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PHYSICS.—*Contributions of electricity to mechanics.*[1]

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The title of this address stems from the observation of the speaker that a surprising number of his colleagues in the field of mechanics received their first professional training in electricity, either as electrical engineers or as physicists specializing in electricity. This observation receives quantitative support from the educational records of the authors contributing papers to the leading American journal in the field of applied mechanics, the *Journal of Applied Mechanics* of the American Society of Mechanical Engineers. An attempt was made to find the educational records of the authors for two recent years of the journal, 1946 and 1947, by reference to *Who's Who in Engineering* for 1948 and *American Men of Science* for 1944. The records were found for the authors of only 28 among the 77 papers printed in these two years. Only 29 per cent of the 28 papers came from authors with an orthodox training in mechanical engineering; 16 per cent came from authors with a major training in electrical engineering. Most of the remaining authors had their basic training in physics and mathematics. It is probable that many of the physicists had elected electricity as their major interest in physics.

It follows that training in electricity is making a real contribution to the advancement of mechanics. The nature of the contribution will be brought out in this paper by illustrations taken in part from the author's own experience in the mechanics of structures. No illustrations will be given from other fields of mechanics, although it would not be difficult to find them.

[1] Address delivered on January 15, 1949, as retiring president of the Philosophical Society of Washington. Received April 11, 1949.

TECHNIQUES OF MEASUREMENT

Force.—It is natural to put force first in a list of the fundamental mechanical quantities that must be measured. The classical means for measuring a force is to balance it with another force, as in the equal arm balance or in an unequal arm balance using the lever principle. An example for the latter is the beam and poise testing machine, which is still in wide use. Closely related to the mechanical lever is the "hydraulic lever" in which the forces are converted into pressures and levers of unequal length are replaced by pressure cells of unequal area. The hydraulic lever is used to measure the load in the large horizontal testing machine of 2,300,000-pounds capacity in compression of the National Bureau of Standards (*1*).[2] These mechanical systems have the virtue of simplicity in principle and of accuracy. Unfortunately they involve the displacement of masses with considerable inertia, so that it is impossible to measure forces that vary rapidly with time. The measurement of such forces requires that the measuring instrument should be either so stiff or so light that its lowest natural frequency is considerably higher than that of the highest frequency Fourier component in the force-time curve to be measured. This requirement is satisfied in any one of a series of electrical dynamometers in which the force causes an elastic strain proportional to it which, in turn, is measured by a wire strain gage attached to the dynamometer. The principle of the wire strain gage will be discussed below. The wire is so light and it is so securely attached to the dyna-

[2] Italic numbers in parentheses refer to the references at end of paper.

mometer that it is able to follow even the most rapid strain variations in the dynamometer. The confidence in wire strain gages has at present grown to the point where they are used even for the weighing of aircraft and for the construction of precision dynamometers. Fig. 1 shows a Cox and Stevens weighing kit (*2*) consisting of three dynamometers of 50,000 pounds capacity, each of which may be placed on top of jacks supporting an airplane at three points. The load on each dynamometer passes through several vertical compression members on which wire strain gages are attached. The output of the wire strain gage on each dynamometer is read on a sensitive Wheatstone bridge. Weights may be determined with an error of less than 50 pounds in 50,000. Fig. 2 shows two experimental precision dynamometers, one of 1,000,000 pounds capacity and the other of 3,000,000 pounds capacity, being developed at the National Bureau of Standards to provide, for the first time, a means for calibrating testing machines for loads greater than 2,600,000 pounds. Each dynamometer is nothing more than a carefully machined steel cylinder to which eight wire strain gages have been attached longitudinally and circumferentially in a pattern which reduces errors caused by temperature variations and by eccentricity of the load on the dynamometer. Fig. 3 shows two less precise dynamometers built for special purposes. The first is a dynamometer of 15,000 pounds capacity for measuring the tension in a cable. It is simply a tension member with four wire strain gages attached in an axial direction. The second is a small experimental compression dynamometer of 80 pounds capacity for measuring rapidly varying forces transmitted through a very rigid

FIG. 1.—Cox and Stevens weighing kit containing three compression dynamometers of 50,000 pounds capacity each.

WALTER RAMBERG, President of the Philosophical Society of Washington, 1948.

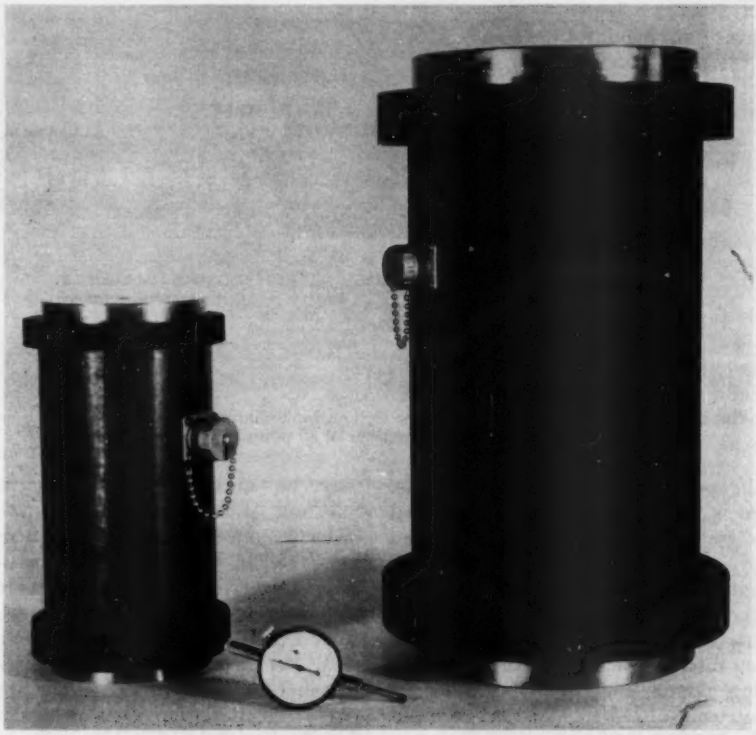

FIG. 2.—NBS experimental compression dynamometers of 1,000,000 and 3,000,000 pounds capacity.

structure such as a hardness testing machine. This dynamometer is interesting from the point of view of the theory of curved elastic membranes. The middle portion of the dynamometer has been machined down to a wall thickness of about 0.004 inch and has been pressed into a corrugation of double curvature with principle radii a, b where $2a$ is the average diameter of the dynamometer and b is the radius of the corrugation. It can be shown from the theory of curved elastic membranes (*3*) that the circumferential strain ϵ_c in the corrugation is given by

$$\epsilon_c = \frac{a}{b}\,\epsilon_a, \qquad (1)$$

where ϵ_a is the axial strain corresponding to the external load. The axial strain is magnified in the ratio a/b according to the theory. A dynamometer of relatively large output and at the same time exceptional rigidity is therefore obtained by bonding a strain sensitive wire to the bottom of the corrugation. Tests of the dynamometer shown in Fig. 3 gave an output somewhat less than the theoretical output given by equation (1); this was ascribed to loss of strain in the bonding medium.

Pressure.—The classical ways of measuring pressure are by the difference in height of a column of liquid as in the mercury barometer or by the deflection of an elastic pressure capsule as in the Bourdon gage, in which the pressure tends to straighten a curved tube, which, in turn, causes rotation of a pointer. Electricity has suggested several other methods of measuring pressure. Extremely small and slowly varying pressures may be measured with the "vibrotron" (*4*) which uses an old principle in strain gage technique (*19*). In the vibrotron (Fig. 4) the pressure variations cause a change in tension in a wire stretched be-

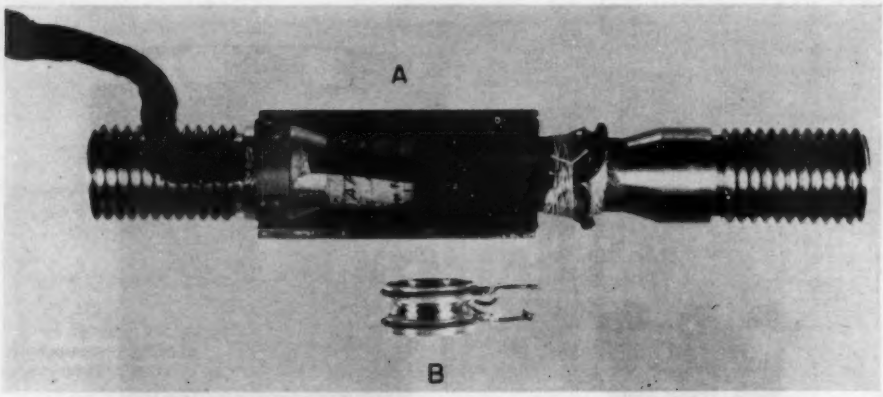

FIG. 3.—Special wire strain gage dynamometers: A, Tension dynamometer of 15,000 pounds capacity; B, compression dynamometer of 80 pounds capacity.

tween the poles of two or more magnets. The wire is vibrated in one of its natural modes of transverse vibration as a stretched string by connecting it into an oscillating electric circuit with feedback. The frequency of the mode will vary with the tension in the wire so that the changes in pressure cause a frequency modulation of the current in the oscillating circuit, which can be either recorded or transmitted to a distant receiver. Larger and more rapidly changing pressures may be measured electrically with the Statham pressure pickup in which the pressure causes an extension of a small bellows, which, in turn, strains an unbonded strain sensitive wire and causes its resistance to change in proportion to the pressure (*5*). Very rapid pressure changes may be measured electrically with piezo-electric gages, in which the pressure causes the appearance of electric charges of opposite sign on certain faces of a crystal of quartz or Rochelle salt. These charges may be converted into a change in voltage on a high impedance circuit and may be amplified and recorded. Gages of this nature have long been used for recording gas pressure in gun barrels and in engine cylinders (*6*).

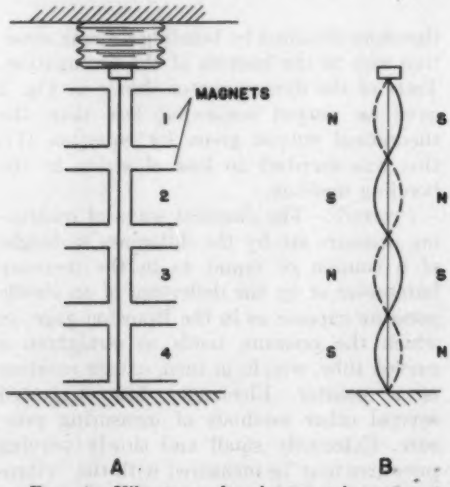

FIG. 4.—Vibrotron for barometric pressure measurements: A, Schematic diagram with wire strung between four magnets and attached to pressure bellows at top; B, mode of transverse vibration of wire with opposite field polarities on adjacent magnets.

Displacement.—Small displacements in structural mechanics are most commonly measured with dial gages in which a rack and pinion is used to convert displacement into rotation of a pointer. In this field, too, electrical methods are being used increasingly. Aleck, Goland, and Morris (*7*) developed a sensitive displacement gage in which the displacement causes strain in a ring which is picked up with wire strain gages again (Fig. 5). One of the most interesting electrical displacement gages utilizes the effect of displacing the core of a small transformer. The Baldwin Locomotive Works have embodied this principle in the design of their "microformer" replacing selsyn motors to transfer small displacements from points on a test specimen to a recorder

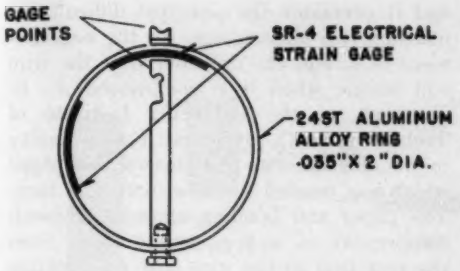

FIG. 5.—Displacement gage of ring type (Aleck, Goland, and Morris).

(*8*). Schaevitz uses the same principle in somewhat different form in his "linear variable differential transformer" (*9*) in which a small magnetic core is pushed in and out of an insulating spool on which three coils of wire are wound coaxially (Fig. 6). A high frequency (1,000 c.p.s.) current is passed through the center coil. This sets up a magnetic flux linking the center coil with the two outer coils. The two outer coils are connected so that the voltages induced in them are balanced when the core is in the central position. As the core is displaced from this position an unbalance voltage is produced which is proportional to the displacement. The unbalance voltage is used to measure or record the displacement of the core. The gage is distinguished by linearity over a remarkably long range; it may be made linear for displacements of 1.5 inches with a sensitivity of about 0.001 inch.

The Statham unbonded wire pickup can be used for the measurement of displacement as well as pressure by simply replacing the coupling with the pressure sensitive bellows by contact to the structure on which displacement is to be measured.

Ross Gunn (*10*) has devised an ingenious and extremely sensitive displacement pickup, called the electronic micrometer. This pickup utilizes the effect of changing the relative spacing of electrodes in a vacuum tube. The vacuum tube contains two plates spaced symmetrically to either side of a fixed cathode. The plate supports are carried outside the tube through a flexible membrane in the envelope of the tube. They are brought to a point for making contact with the structure on which displacement is to be measured. The displacement causes one of the two plates to move toward the cathode and the other to move an equal distance away from the cathode. This results in an unbalance current in a Wheatstone bridge into which the plates and cathode are connected. The symmetrical construction of the plates and cathode in the tube makes the bridge insensitive to small variations in the supply voltage, since this will affect the currents to both plates equally. It is possible to detect displacements of less than 0.000001 inch with this pickup.

Strain.—Perhaps the greatest single contribution which electricity has made to mechanics during the past 10 years is the wire strain gage, which has already been mentioned above as a means of measuring mechanical quantities other than strain.

Before the advent of the wire strain gage strain measurements were made with any one of a great number of ingenious strain gages developed over the past hundred years. Most of these gages used the mechanical lever principle to magnify the extremely small displacements to be measured; examples of these are the Huggenberger (*11*)

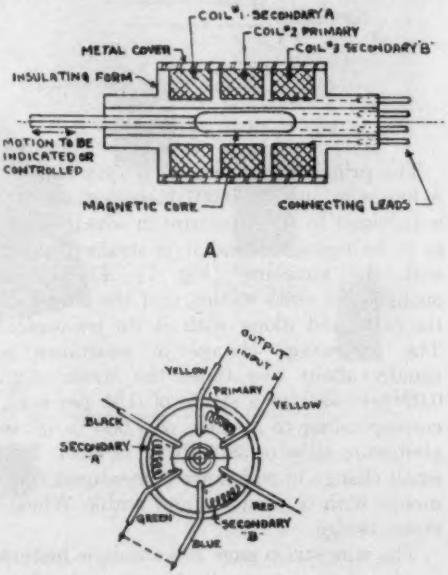

FIG. 6.—Linear variable transformer (Schaevitz): A, Cross section; B, end view showing connections.

and the Whittemore strain gages (*12*). Others use a combination of mechanical and optical lever, such as the Tuckerman optical strain gage (*13*), which is still a preferred instrument when a precision of better than 1 per cent is required. Unfortunately these gages are expensive; they are difficult to attach at remote locations and they will not follow rapid changes in strain. The wire strain gage has attained its popularity primarily because it is cheap, it is easily attached at inaccessible locations, and it will follow rapidly varying strain, and secondarily because convenient instruments have been developed which permit accurate measurements to be made by relatively inexperienced operators.

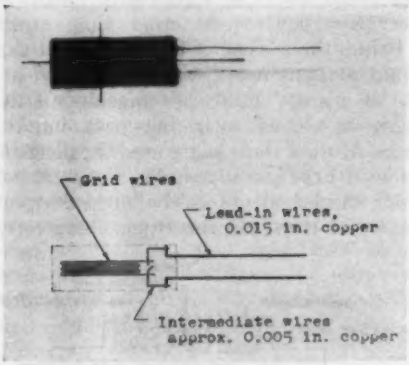

FIG. 7.—Wire strain gage.

The principle of the gage is very simple. A fine wire, usually 0.001 inch in diameter, is fastened to the structure in which strain is to be measured and it is strained along with the structure (Fig. 7). The strain changes the cross section and the length of the wire and along with it its resistance. The percentage change in resistance is usually about two times the strain, e.g., 0.02 per cent for a strain of 0.01 per cent, corresponding to a stress of 1,000 lb/in^2 in aluminum alloy or 3000 lb/in^2 in steel. This small change in resistance is measured commonly with a sensitive and stable Wheatstone bridge.

The wire strain gage has a unique history insofar as it is a purely American development. The development started with the well-known phenomenon, just outlined, that wire changes in resistance as it is strained, and it overcame the principal difficulty in utilizing this phenomenon for the measurement of strain, the difficulty that the wire will buckle when it is compressed. E. E. Simmons, of the California Institute of Technology (*14*), overcame this difficulty by bonding the wire to a piece of thin paper which was bonded to the structure in turn. The paper and bonding material transmit compressive as well as tensile strain from the structure to the wire without buckling the wire. Important contributions to the development of the wire strain gage were made at the same time by other workers in American laboratories, notably D. S. Clark and G. Daetwyler at the California Institute of Technology (*15*), Profs. A. C. Ruge and A. V. deForest at the Massachusetts Institute of Technology, and the engineers of several aircraft companies who developed wire strain gages for their own use. At present most of the gages are made by the Baldwin Locomotive Works under the trade name SR-4 strain gage. Over 250,000 of these gages are being sold per year.

Fifteen different types of gages, among them several of the SR-4 gages, were studied by W. R. Campbell at the National Bureau of Standards to determine their performance under various conditions of use. Such tests were urgently needed at the time to indicate which ones among these gages had the best performance in respect to uniformity, accuracy, linearity, sensitivity to transverse strain, sensitivity to temperature changes, etc. Uniformity is of particular importance since the wire strain gage cannot be calibrated either before or after use. The calibration constant must be determined on sample gages from the same batch, and it is then used on the assumption that the calibration of the sample gages applies to all the gages in the batch. The accuracy with which strain can be measured with an uncalibrated wire strain gage of the batch is, therefore, limited by the possible deviation of its calibration factor from that of the calibrated sample gages. This limitation does not apply to wire strain gages attached to pickups which are calibrated themselves. In that case the wire strain gages are calibrated indirectly in terms of the quantity measured by the pickup, e.g., force or dis-

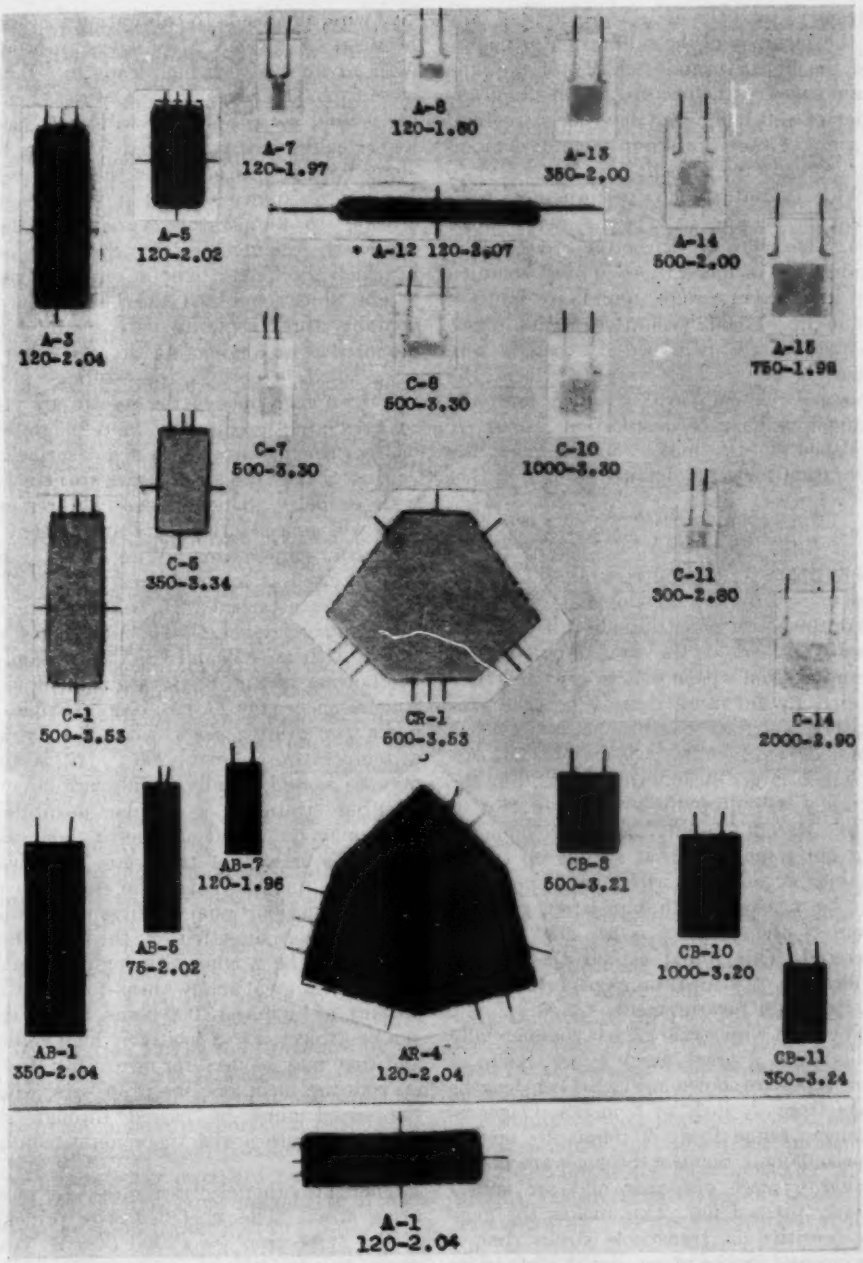

FIG. 8.—Commercially available types of wire strain gages. Legend below gages indicates SR-4 type number, resistance in ohms, and calibration factor.

placement, and the accuracy is limited only by the accuracy of the calibration procedure and the linearity and stability of the wire strain gages on the pickup. Accuracies of the order of ±0.1 per cent have been realized in some of the wire strain gage dynamometers already mentioned.

Wide variations in performance were found among the 15 types of gages tested (*16*). The gages of the better types, which incidentally included those in most common use at present, were found to indicate strains up to 0.002 accurately within about 1.5 per cent. The indicated strain is here taken as the strain computed from the measured change in resistance and the nominal values of calibration factor K furnished by the maker of the gage; the calibration factor is defined by

$$K = \frac{\Delta R/R}{\epsilon}, \qquad (2)$$

where ΔR = change in resistance R of the gage caused by strain ϵ along the gage line.

For the better gages the calibration factors K were found to be the same in tension and in compression within 0.5 per cent and they differed by no more than 1 per cent for gages from a given batch.

Wire strain gages may be used for measuring much larger strains than 0.002, but the accuracy will drop by a factor of two or three. Recent unpublished developments hold out some hope that strains up to the breaking strain of the wire, over 20 per cent, may be measured with wire strain gages, if errors of the order of 5 per cent can be tolerated. This would extend the field of application of wire strain gages into that of plastic strain measurement.

The SR-4 wire strain gage is commercially available in a great many types. Some of these types are shown in Fig. 8. Gage lengths range from $\frac{1}{16}$ inch to 6 inches. Gage resistances range from 60 ohms to several thousand ohms. Some of the gages are wound around a piece of paper and are subsequently pressed flat. This makes the gage less sensitive to transverse strain than a gage wound in one plane, but it adds to its rigidity, thereby making it less suitable for measuring strain on thin sheet and more difficult to attach to a curved surface. Several materials are used for the strain sensitive wire; this leads to calibration factors K between 1.7 and 3.5. Most gages are wound with advance wire, which leads to a factor close to 2. The gages of the C series, Fig. 8, are wound with iso-elastic wire; this has a higher calibration factor than advance, but along with it has a higher thermal coefficient of resistance so that it is more susceptible to temperature variations; these gages are recommended for dynamic tests in which the higher temperature coefficient is not objectionable. Gage CR-1, Fig. 8, contains three separate wire strain gages mounted at an angle of 45° to each other in a so-called "rosette"; the readings along the three gage lines of the rosette are used to calculate the direction and magnitude of the principal strains on a flat surface.

Most of the SR-4 strain gages are attached with ordinary "Duco" household cement. This will give a satisfactory attachment at ordinary temperatures. Wire strain gages may be used at temperatures up to 300°F. if they are attached with bakelite cement. Six commercial bakelite bonded gages are shown with an AB and CB designation at the bottom of Fig. 8. By attachment with Sauereisen cement it has been possible to make wire strain gages which indicate strain at temperatures above 1,200°F. (*17*). Gages may be wound spirally to measure circumferential strain on a circular membrane. They may be wound in a herringbone pattern (*18*) to have a transverse sensitivity which is adjusted so that the change in resistance is proportional to stress rather than strain in the direction of the gage line. Gages may be wound with high resistance wire with a great many turns to give a resistance as high as 15,000 ohms. Such gages can be subjected to a relatively high voltage and they may be used for measuring strains on rotating members like propellers, where the signal must be passed through slip rings and brushes with unavoidable contact potentials.

There are other electrical means for measuring strain. The stretched wire principle of the "vibrotron" was used over 20 years ago in Russia (*19*) to provide an "acoustical strain gage." The change in spacing of condenser plates has been used (*20*). Strain gages have been built using the photoelectric effect. In one such strain gage, due

to Gadd and Van Degrift (*21*), the strain causes relative motion of two gratings of alternate transparent and opaque bands, thereby changing the amount of light transmitted through the gratings. The variations in light are picked up with a photoelectric cell and recorder. The gage has a gage length of $\frac{1}{16}$ inch and an over-all magnification of 30,000.

Acceleration.—The measurement of acceleration was in a primitive state before the use of electrical methods. The commonest procedure was to trace the displacement of the accelerated body as a function of time and differentiate the displacement twice in respect to time. This brought with it the magnification of errors that is familiar to anyone who has tried graphical differentiation. Another method is to suspend a mass from a spring and scratch the displacement of that mass relative to the accelerated body with a stylus on a rotating drum. This method suffers from the tendency of the spring-supported mass to vibrate as a seismometer in response to high frequency vibration, and the inability of the mass to follow rapidly changing accelerations.

It has not been possible even with electrical methods to build accelerometers that cover all needs. However, the frequency range and accuracy have been greatly extended by using several of the electrical pickups already described above.

The unbonded wire in the Statham pressure pickup was first used by the Statham laboratories for designing acceleration pickups ranging from a capacity of 1.2 g at a natural frequency of 70 c.p.s. to a capacity of 200 g at a natural frequency of 1,400 c.p.s. (Fig. 9). The wire W is made sensitive to acceleration rather than pressure by attaching it to a mass M instead of a bellows. The mass is guided so that it will stress the wire by an amount proportional to the component of acceleration parallel to the wire. The piezo-electric pressure pickup can be converted in the same manner to a high frequency acceleration pickup.

The effect of relative displacement of electrodes in a vacuum tube, already utilized by Gunn for measuring displacement, was utilized at the National Bureau of Standards for measuring accelerations (*22*). For this purpose the supports of the plates P, Fig. 9, to either side of the fixed cathode C were made flexible rather than rigid, and they were designed so that the deflection of the plates relative to the cathode would be proportional to the component of acceleration normal to the plates. Vacuum tube accelerometers have been built both here and in England with natural frequencies ranging from 700 to 1,200 c.p.s. and capacities up to 150 g.

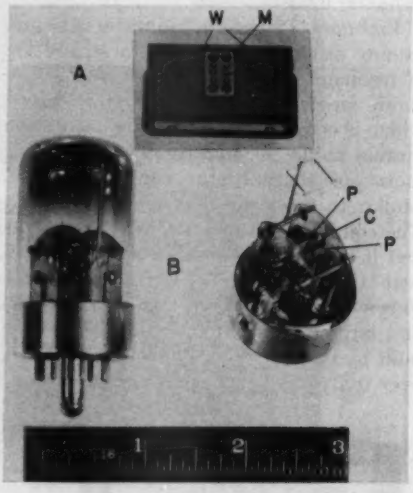

FIG. 9.—Electric acceleration pickups: A, Statham acceleration pickup, capacity 12 g; B, NBS vacuum-tube acceleration pickup, capacity 150 g.

Applicability of electrical pickups to measurement of several mechanical quantities.—The preceding description of electrical pickups for measuring mechanical quantities, though very incomplete, brings out not only the variety of pickups, but also the fact that any given type of pickup can be used for the measurement of more than one mechanical quantity.

A comprehensive paper describing electrical techniques for measuring mechanical quantities might well be arranged by type of pickup rather than type of mechanical measurement. Any good displacement pickup, for instance, can be used for measuring force, since force will cause displacement in an elastic dynamometer. It can be used for measuring pressure, which causes displacement of a bellows. It can be used for measuring strain, which results in relative dis-

placement over a finite gage length. It can be used for measuring acceleration of a spring supported mass. Any good linear pickup will thus have at once an extensive field of application in mechanics.

TESTING TECHNIQUES

Electricity has made a major contribution also to the techniques of mechanical testing of structures, particularly the testing under dynamic loads.

Vibrators.—Nearly all vibrators for maintaining elastic structures in a steady state of resonant vibration are electrical. Fig. 10 shows an electrodynamic vibrator of a type which is coming into increasing use to excite normal modes in aircraft. The "push-pull" motor of the vibrator consists of a coil similar to the voice coil in a loud speaker. The coil is placed in a strong magnetic field and it is driven by passing alternating current through it. The particular vibrator shown in the figure is among the earliest and largest of its kind. It is one of a pair built by the Goodyear Zeppelin Corporation over ten years ago to make fatigue tests of wing beams at the National Bureau of Standards (*23*). Each vibrator has a capacity of 1,250 watts at 60 c.p.s.

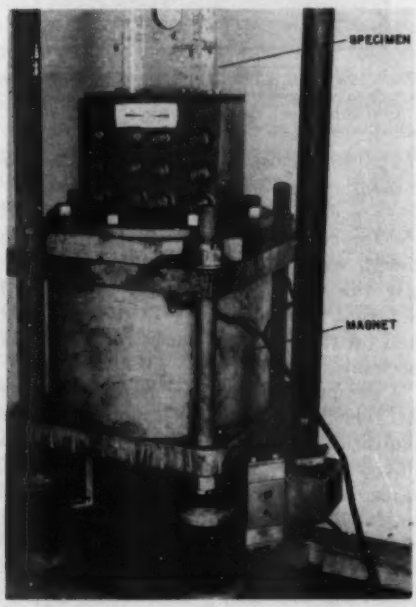

FIG. 10.—Electrodynamic vibrator of push-pull type; output 1,250 watts at 60 c.p.s.

Dynamic recording.—Electricity has revolutionized the recording of mechanical quantities, particularly during a dynamic test. The output of most electrical pickups used in such a test is so small that it requires amplification before it is fed into a string galvanometer or cathode ray oscillograph. Fig. 11 shows a 6-channel recording equipment which is in constant use at the National Bureau of Standards. This equipment will take the output from four wire strain gages into four Wheatstone bridges fed by 1,000-cycle alternating current. Each one of the four bridges is supplied with separate controls for balancing the resistive and reactive component of the voltage. The unbalanced voltage is then amplified to the desired level, passed through a band pass filter with flat response up to 100 c.p.s. to remove hash, rectified, and fed into four of the six galvanometers in a 6-channel recorder. The remaining two channels of the recorder can be utilized for timing and for recording from a pickup with high output, not requiring amplification, such as the vacuum-tube accelerometer.

It is not surprising after an examination of this recording equipment that electronics engineers are as important in dynamic tests of structures as mechanical engineers and that the cost of electrical equipment frequently outweighs that of the mechanical equipment. The cost of the recorder for one wire strain gage is approximately 1,000 times that of the gage itself.

ANALYSIS

Electricity has led the way in the analysis of many important problems in the mechanics of structures.

Electrical analogues.—The equations for the flow of current in certain electrical conductors under given differences of potential are identical mathematically with the equations for the velocities of points in an analogous mechanical structure under given external forces.

Den Hartog showed, for example (*24*), that the performance of the damped vibration absorber of Fig. 12 could be derived

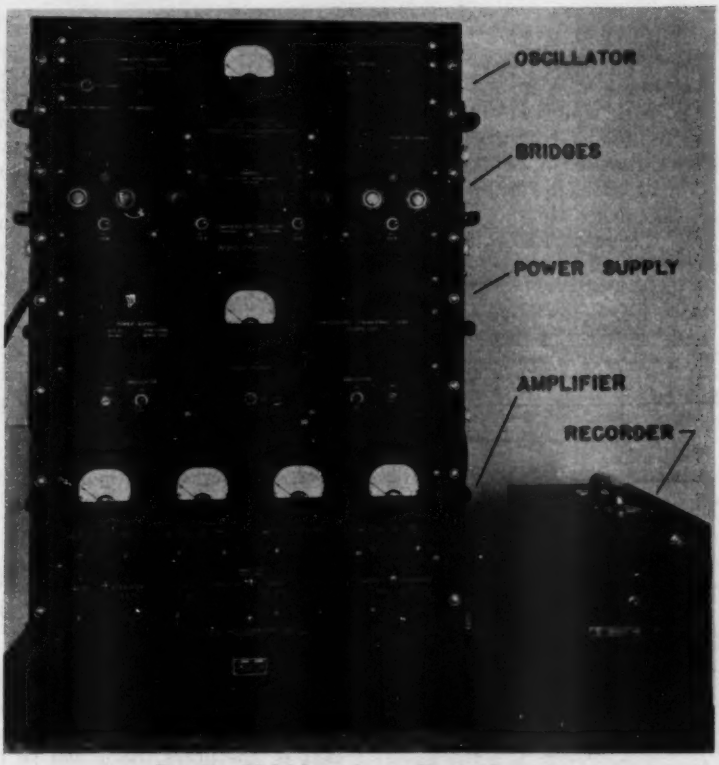

FIG. 11.—Multichannel recording equipment.

from the impedance of the analogous electrical circuit of Fig. 13. This impedance is readily obtained in terms of complex numbers by methods familiar to electrical engineers.

The electrical analogue is useful also for an experimental analysis of the effect of changes in mass distribution, stiffness, and frequency of applied alternating forces on the stresses set up in the members of a structure such as a railroad bridge traversed by a locomotive. It is much easier to change the inductances, capacities, and the frequency of the applied voltage in the analogous electrical circuit than to change the corresponding mechanical parameters of the bridge. V. Bush (*25*) estimates that a structural analysis may be made on the electric analogue of a railroad bridge with an uncertainty of only 3 per cent in the stresses determined from the voltages at various points on the electric circuit.

Analysis of transients.—Electricity has pointed the way to the rational analysis of transients in mechanical systems. Mechanical transients have become an urgent problem in aircraft during the last few years. The problem arose with the occurrence of failures in the wing and tail structure of large transport airplanes under apparently normal landing conditions. The stresses computed corresponding to these landing conditions, on the usual assumption that the airplane was decelerated as a rigid body, were far below those required to explain failure. The "rigid body" analysis was obviously inadequate for designing against landing impact. A more refined analysis was necessary to determine the transient elastic deflections of the airplane structure in response to the landing impact. The response in each mode of vibration of the airplane structure (*26*) can be found readily from Duhamel's integral

$$q_i(t) = \frac{1}{M_i \omega_i} \int_0^t Q_i(\tau) \sin \omega_i (t-\tau)\, d\tau \quad (3)$$

where $q_i(t)$ is the deflection in the i-th mode, of frequency ω_i, of an equivalent linear oscillator of mass M_i, deflected by an external force $Q_i(t)$. The transients measured during landing tests of a model wing (*27*) were found to be in agreement with those computed by superimposing the responses q_1, q_2, q_3 for the first three modes of vibration.

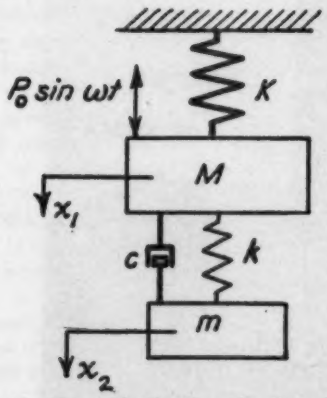

FIG. 12.—Damped vibration absorber of mass m, spring k, and damping c attached to undamped machine of mass m on spring k, subjected to an alternating force $P_0 \sin \omega t$.

Duhamel's integral is a special case of Heaviside's famous superposition integral for determining the transients in electrical networks. The mechanical engineers concerned with the analysis of the problem of landing impact are finding that Heaviside and his disciples in the development of the operational calculus have already pointed out short cuts to solutions of some of their problems. Mechanical engineers are forced to think of their structures as mechanical circuits with impedance and admittance.

Electrical computers.—Electricity is making a great contribution to mechanics in speeding computation.

There was a marked increase in speed of computation when the hand-driven crank of the computing machine was replaced by an electric motor. A further increase was realized with a reduction in mass of the moving parts and later with the replacement of mechanical counters by relays of the type used in telephone exchanges. The range of application of computers was at the same time greatly increased with the introduction of punched cards for the storage of data and for use as an input medium in place of the human operator. By these means it was possible to transform a great variety of computations to a purely automatic procedure; however, the speed of computation was limited by the inertia of the moving parts of the machine. The next great advance was made with the development of the electronic computer which utilizes electrons, with their negligible mass, to carry out the operation of addition and subtraction and with them those of multiplication and division. Such an electronic computer is the ENIAC (Electronic Numerical Integrator And Calculator) developed at the Moore School of Engineering of the University of Pennsylvania, and now in operation at the Aberdeen Proving Ground. The basic unit of electronic computers (*28*) is a circuit familiar to radio engineers as the Eccles-Jordan trigger circuit or multivibrator. The trigger circuit is an electronic relay consisting of a pair of vacuum tubes which are connected so that at any time one and only one of the pair can be conducting. The trigger can be reversed, that is, the other triode can be made conducting in less than one-millionth of a second. Ten triggers are used in the ENIAC to transmit any digit between 0 and 9. It is not surprising, therefore, that the ENIAC uses 18,000 vacuum tubes to handle 9-place

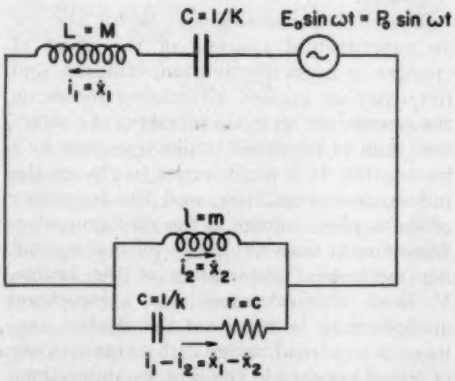

FIG. 13.—Electrical circuit analogue of mechanical system of Fig. 12.

numbers. However, thanks to the small reaction time of these tubes it is possible to multiply two 9-place numbers in less than 0.003 second as compared to about 15 seconds with a conventional computing machine.

The electronic computer is so rapid that the temporary storage of information between cycles and before transcription becomes a major problem. Several ingenious schemes have been devised to accumulate information including registration on a magnetic tape and temporary retention in the form of sound waves passing repeatedly through a column of mercury. An adequate description of these schemes would go beyond the scope of this paper as well as beyond the competence of the author.

The principal point to note is that the automatic-sequence computer steps in to overcome the barrier of human fatigue involved in carrying out thousands and thousands of routine operations. It has stepped in so effectively that several aircraft companies have installed large scale computers for their own flutter computations. Ballistic laboratories are supporting the development of computers because among other things they can obtain an answer to a ballistic problem between successive firings of a gun. The National Bureau of Standards is coordinating the development of automatic sequence electronic computers for several Government agencies, among them the Bureau of the Census, the Office of Naval Research, and the U. S. Air Forces. Automatic-sequence computers will find many new uses in the solution of mechanical problems as methods are mastered for reducing the solution of these problems to routine numerical procedures of a type that can be handled by the computer.

CONCLUSION

We cannot help being impressed by the great and growing contribution of electricity to mechanics. Electricity has accumulated a credit which mechanics can probably never pay off, since there is little chance that mechanics will discover an agent as nimble, as controllable, and as universal as the electron for carrying out tasks that seemed impossible before. A similar story of indebtedness to electricity can be told about the other fields of engineering. It is really part and parcel of the essential unity of all scientific knowledge. All branches of science must stay in debt to each other in order to advance to their greatest potentialities. It is not unreasonable to hope that some future "Past-President" of this Society may give another illustration of this essential unity of science by talking on the contributions of mechanics to electricity.

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ETHNOLOGY.—*The animal that cannot lie down.*[1] HORACE P. BECK, Temple University. (Communicated by W. N. FENTON.)

This paper has a twofold purpose—to suggest the possibility of native origin for more of our American folklore than is generally accepted and to indicate evidence of man in North America in late Pleistocene times through fossilized legends. To these ends the old theme of the stiff-legged elephant will be treated with the idea, not that one swallow makes a summer, but rather that one story may, if closely followed, indicate further possibilities. This story, because of its many peculiar aspects, has been discussed widely among folklorists in this country. Let us, in order to get a rounded picture of the problem, look first to Europe and trace, in a general way, the history of the Creature-Who-Could-Not-Lie-Down.

About 350 B.C., to give our tale some antiquity, Aristotle remarked, "What is asserted of the elephant by some is not true (i.e., he cannot bend his legs nor sit) for he can do both, except that he cannot, on account of his weight, at one and the same time bend each fore leg, but he can alone bend one leg and recline on one side, and in that manner he sleeps (leaning against some wall or tree)."[2]

Leaping a millennium, we come to the Anglo-Saxon and his poems of the Whale, the Panther, and the Partridge. Since these stories parallel the Middle English Bestiary, it is usually believed that they are the vestigial remains of an Anglo-Saxon Bestiary, long since lost to us. If that be the case, the Anglo-Saxons must have been acquainted with this elephant story, since it appears in the Middle English Bestiary. Here, the tale of Aristotle has gained color:

In Ynde ye may Elephants see
Big and burly in body they be
. . . . . .
One thing they have most in thought,
That they ne'er to a fall be brought
Since they be lacking the power
To rise again in that hour.
. . . . . .
He doth seek to himself a tree,
. . . . . .
And against the trunk doth lean,
When weary with walking I ween.
When the hunter this doth know.
. . . . . .
Seeing where the beast doth go
This his rest to get
Then the tree doth he saw away
. . . . . .
His work with care doth hide.
. . . . . .
Then cometh the monster I ween
On his side 'gainst the tree doth lean.
In the shade of the tree so tall,
Doth he sleep, and together they fall.[3]

[1] Received March 31, 1949.

[2] TAYLOR, T., *The history of animals of Aristotle and his treatise on physiognomy translated by T. Taylor:* 36. London, 1809.

[3] WESTON, JESSIE, *Chief Middle English Poets:* 312. Boston, 1914.

So far this story fits a pleasant pattern. Scholars, during Middle English times, were interested in Greek literature, in Latin translation, and took what they found there for fact. Seeing the story about the elephant, they believed it, embroidered it, gave it a religious twist, and handed it out for gospel. Unfortunately, there is a flaw in the picture.

When Caesar went to Gaul, he recounted in the sixth book, Chapter XXVII, of his Commentaries, the following small anecdote:

> There are also animals that are called elks. The shape of these, and the varied color of their skins, are much like does, but in size they surpass them a little and are destitute of horns, and have legs without joints and ligatures; nor do they lie down for the purpose of rest, nor, if they have been thrown down by any accident can they raise or lift themselves up. Trees serve as beds to them; they lean themselves against them, and thus reclining only slightly they take their rest. When the huntsmen have discovered . . . whither they are accustomed to betake themselves they either undermine all the trees at the roots or cut into them so far that the upper part of the trees may appear to be left standing. When they have leant upon them,—they knock down by their weight the unsupported trees, and fall down themselves among them.

These Gallic people had never heard of Aristotle, nor could they read Greek, yet they had a story identical to Aristotle's except that it referred to a different animal. The writers of The Bestiary, remembering this legend from their own past simply adopted Aristotle's version, as an improvement on their own myth, gave it a religious twist and handed it out anew—common practice among the folk.

Since elephants did not inhabit Greece, it is safe to say that Aristotle picked up the story from people who lived with elephants and believed it because there was a similar belief in Greece. Thus we have the story in two, and possibly three, widely separated regions—India,[4] Europe, and the Near East. It looks universal.

If this is true, then we should expect to find the tale in China and Siberia. There are legends concerning the creature in both these regions, but they are of the *ipso facto* variety rather than any real memory of a living monster. This type of myth we will discuss later.

We know that at the time of the coming of the whites to this country this fable was popular in England. It was well enough known that Shakespeare, writing for the masses, devotes a line of *Troilus and Cressida* (Act I, Scene 2) to the myth. "Ulysses: 'The elephant hath joints, but none for courtesy'." As late as 1646 Sir Thomas Browne felt that this belief was prevalent enough in the minds of his fellow countrymen to be exposed and he therefore devoted a substantial portion of his *Vulgar errors* to the theme "That an elephant hath no joints." Therefore, is it not possible that the English told this story to the Indians, who retained and repeated it to the present day?

It is true that many European folk tales were told the Indian. However, when the language barriers and all the attendant difficulties of the time are considered, it does not seem probable that such an involved story would be told in the early days of the first contact. Later this would be possible, but by the end of the seventeenth century the idea of jointless animals was practically dead. Further, it is not likely that the Indian would accept a story the ideas of which were completely unknown to him. It is not usually the case with the folk. They will adopt things they can understand or have already in their culture, but usually the adoption is, like the Bestiary, an embroidery. This immediately raises the question of Lady Godiva, knights in armor, castles, and fairies—obviously European folk tales. What about them? One need only read the early accounts of the Jesuits and explorers like Cabesa Da Vaca and Cartier to discover that the Indian had tales similar to these white stories—The Seven Cities Of Cibola, The Spring Of Life, and The Land Of Headless Men are but a sample of the host of stories in this vein.

Let us now examine Indian tales relating to this Creature-Who-Cannot-Lie-Down and then attempt to put it into the idea of a fossilized memory of the mammoth.

F. G. Speck records from the Penobscot in Maine the story of White Owl and His Escape From the Witches and Great Beasts. The myth has several stories woven into it,

[4] For a further discussion of the possibilities of the mammoth being known in India, see FALCONER, *Paleontological memoirs:* 375. London, 1868, wherein there is an account of the elephant-tortoise myth linking it to prehistoric times.

but the one about the great beast predominates.

A culture-hero called White Owl, while traveling to the south, discovers some moving hillocks covered with brown vegetation. Upon closer observation he finds that in reality the hillocks are great long-toothed beasts who could drink for half a day and were so huge that they could not get up if they lay down. Deciding, in a leisure moment, to kill them he found out where the animals went at night and observed that they slept leaning against trees. Accordingly he cut the trees part way through, and when the creatures leaned against them both tree and animal fell to earth. Since the fallen animals were unable to rise again, Snowy Owl proceeded to shoot them with his magic arrows.[5]

From Labrador, both Dr. Speck and Dr. Strong record versions of this story. In this case the beast is called Katci-to-wushk, "Stiff-Legged Bear." The story begins when Katci-to-wushk kills a man and a woman but leaves behind a newborn baby who is reared by his sister until he goes out to seek his parents' murderer. "He found large round deep tracks in the snow which he followed . . . Katci-to-wushk came and found Djakabish in his track and hit him with his long nose and knocked him down. Djakabish shot him in both hips. The monster said, 'eat my head but keep my ears for your bed'."[6]

Later the head became rejuvenated and set out after Djakabish, who heard its great teeth rattling and was warned in time to kill it.

Although these are all modern accounts and localized to the Northeast, the distribution of the myth is widespread and has been recounted by the early writers of the eighteenth and nineteenth century. Charlevoix remarks in 1744, "There appears to be among the barbarians a pleasant story of a great moose who makes all other moose look like ants. Its legs, they say, are so high that eight feet of snow does not bother them; its hide is so thick that no kind of weapon can penetrate it, and it has a sort of arm which protrudes from between its shoulders and is used as we use ours."[7]

A southern writer, early in the period of colonization, remarked that the moss growing on the trees is the regeneration of the hair of a great beast that roamed through the forest and had its hair torn out by the tree limbs.

James Kenny reports in 1761, "Strange Indians from beyond the Mississippi said 'that their country has many very large horses in it which never lyes down to sleep but leans against a tree for that purpose.' "[8]

One of the more interesting legends of the eighteen century and one that would bear a little discussion is one recorded by Dr. Samuel Mitchill in 1795 and was purported, by him, to relate to the exploits of the famous, but questionably mortal, Delaware Chief, Tammany. Among other typically "culture hero deeds" surrounding him Mitchill says:

> Frustrated in this scheme, (to destroy Tammany) he (the evil spirit of the North) brought from the side of Lake Superior, alarming droves of MAMMOTHS, carnivorous animals, and especially loving to feed upon human flesh. These he turned loose upon the Tammanial Territories, and many deaths and much devastation they caused. They were so swift that nobody could overtake them, and so ferocious that they filled whole villages with terror. Arrows fell blunted from their skins and clubs assailed them in vain. From some prisoners brought home in an expedition against the Indians of the Tide-Waters, the Tammanites had learned the use of seasoning for their food, and a part of the tribute paid to their conquerors by the Atlantic Nation, was dried fish and salt. This latter they caused to be brought thither in vast quantities, and the creatures of the wilderness, attracted by the diffusion of its atoms thro' the air, flocked around the magazines, and pawed and licked the dust impregnated with the smallest saline particles. They grew so fond of it that Tammany ordered large spots of ground to be sprinkled with salt that the wild animals drawn thither might fall a more easy prey to the hunters, who laid in wait to kill them. Among others came the mammoth, who was remarkably ravenous of the product of the ocean, and when intent in gratifying his palate, was led into the covered pits dug across his paths by the direction of Tammany, and there expired impaled on the sharpened points of trees which tore to pieces his belly and bowels as he fell. Thus the country was cleared of those monsters, whose bones discovered

[5] SPECK, F. G., *One of Caesar's anecdotes among the Indians of eastern North America*. Alumni Register Univ. Pennsylvania **19** (9): 686–690. 1917.

[6] STRONG, W. D., *North American Indian traditions suggesting a knowledge of the mammoth*. Amer. Anthrop. **36**: 83, 84. 1934.

[7] CHARLEVOIX, PIERRE F. X. DE, *Journal d'un voyage fait par ordre du roi dans l'Amerique septentrionale* **5**: 185. Paris, 1744.

[8] MASTERSON, J. R., *Travelers' tales of Colonial natural history*. Journ. Amer. Folklore **59**: 55. 1946.

to this day at the Licks, confirm the reality of the story.[9]

This anecdote bears some discussion, especially when we remember that Washington Irving took umbrage at Dr. Mitchill and spent some little time discrediting him. In the first place, we know that Tammany, if he did live, existed, in all probability, in the seventeenth century—well past the day of mammoths. Still, it would be possible, presumably, to have old legends collect around a relatively modern epic hero. In fact, that is usually the case. However, we may be certain that the term "mammoth" is the mouthing, not of the Delaware, but of Dr. Mitchill. It would stretch a point indeed to believe that North American Indians used a Russian word to describe a prehistoric elephant. Other writers refer to this creature as an elk, great beast, horse, bear, and so on and then list its properties.

Next we come to the idea that the mammoth was carnivorous. True, other accounts describe the animal as man-eating, but Mitchill's use of the word, coupled with the fact that William Hunter as early as 1741 had erroneously believed the mammoth to be carnivorous through an examination of its teeth, leads us to suspect that the worthy Dr. Mitchill was to some extent drawing upon written sources. This is further emphasized when he uses the "present day" finds of bones near Salt Licks which further reenforced the idea that the tale was, as we might say, *ipso facto*.

Another feature, and perhaps the most interesting one of all, is to be found in the manner in which these creatures were taken. It is true that certain tribes in the Northeast did employ pitfalls until a fairly recent date. In fact, one may see depressions in the woods of Nova Scotia today that the Micmac claim were placed in moose paths to catch that animal. But the stake pitfall is another matter. We know that they existed in the Northwest and Southwest. They also existed in Africa. Whether they ever existed in the Northeast can not, of course, be determined. This author, in an extended survey of traps has, as yet, found no reference to any such taking device. This brings up the question as to whether Dr. Mitchill obtained his details from an Indian or from a Negro slave. If he obtained it from an Indian, the reference must stand as an unique and extremely early one from this region.

In summary, we may conclude that the better part of this story is of continental or foreign origin. Still, the other legends surrounding Tammany, that Mitchill sets down, have an authentic ring and are told plausibly, such as How Tammany Got Tobacco, Chained the Wind, etc. It is also easier to improve a story than it is to fabricate one. Therefore it is safe to believe that at least part of this tale did exist among the Delawares at one time and that Dr. Mitchill merely improved upon it. Thus we find the story of The Great Beast in still another locality and among a people recognized as ancient among the other tribes of the Northeast and called by them Lénni Lenape.

Still another tale, not unlike Mitchill's, comes from the Tuscarora. Unfortunately the date is late, and Hewitt, like Mitchill, uses terms throughout the tale that could not, logically, be ascribed to the Indians. Like so many of the Six Nations peoples' tales, this one is full of foreign influence and highly developed as a literary masterpiece. Still, it gives one food for thought and aids in piling up material concerning the mammoth memory on this continent. The pertinent part of the longer tale is as follows:

> There was once an orphan boy who grew up among strangers and so fared very poorly but he grew to be a man of more than ordinary strength and agility. He was gifted also as an enchanter, an expert in the craft of the wizard. When he became of mature judgment he asked the oldest and most experienced man among his people if there was a place where man could not go, and he was told that to the Southward there must be something that was supernatural and monstrous for none of those who had gone far in that direction ever returned. So the orphan started off in that forbidding direction. After he had traveled three days and had just crossed a river by walking on the water, he was astonished to see U-ya-kwa-her following closely a bear and quickly to overtake and kill it with one blow of its trunk, and to see it rapidly retrace its steps and soon burst forth from the thickets a lion closely pursued by U-ya-kwa-her which with a few strides overtook and killed the lion with one blow of his trunk, crushing the heads of both but not

[9] MITCHILL, SAMUEL, *The life, exploits and precepts of Tammany: Read in the Old Presbyterian Church in the City of New York on Tuesday, the Twelfth of May, 1795:* 7–8. New York, 1795.

attempting to eat either as U-ya-kwa-her did not eat flesh. But now the orphan saw that U-ya-kwa-her would then perceive his presence and follow to destroy him, so he ran a short distance and climbed a large tree, and before he had climbed up very far he saw that U-ya-kwa-her was pursuing him; it soon came up to the tree and without looking upward which power it had not, it began digging around and thus to uproot the tree. Before long the tree began to topple and the orphan was ready to run down the tree to its base, for when the tree commenced to fall U-ya-kwa-her ran towards the place where the tree would fall in order to find its supposed victim dead among the branches and by the time U-ya-kwa-her found the orphan's tracks on the top of the tree the orphan was quite a long way up another tree, and U-ya-kwa-her would follow him thither and immediately begin digging up the tree and so soon as it would begin to fall U-ya-kwa-her would immediately run to the place where the tree would fall and that would enable the orphan to run down the tree as it became sufficiently inclined to enable him to do so, and U-ya-kwa-her would be looking for him among the branches of the tree top. Thus it dug down many trees. Finally he managed to go from one tree top to another and so a second and a third time so that when the tree he climbed fell the U-ya-kwa-her was not able to find his tracks. So the monster began immediately to go in a circle around the tree until the circle became so large that on one side it reached the river where the orphan had crossed walking on the water so he saw that he could make his way to the river without having to cross the last circle long before the beast would be back and his tracks would be hidden by the waves. So the orphan came down the tree and made his way down to the river re-crossed it as he had by walking on the water. He made his way home where he related what had befallen those that had gone there but never returned for he saw their bones lying in many places the victims of the monster that had chased him so unsuccessfully.[10]

David Thompson, writing the Narration of his exploration, 1784–1812, edited by J. B. Tyrrell in 1916, mentioned the fact that the Athapaskans told him there was a tundra animal that much resembled the mammoth.

Today, there is a legend among the Chitimacha: "A long time ago, a being with a long nose came out of the ocean and began to kill people. It would root up trees with its nose to get at people in the branches."[11] And among the Indians of Massachusetts there is a myth about animated "haystacks" that walked along the beach at Marthas Vineyard.

These are but a few of a host of stories and tales, both past and present, concerning this creature. They cover the length and breadth of North America, and all of them seem to be rough descriptions of some creature with the following characteristics: Huge size; terrible, long teeth (in one instance, at least, curved spears long enough to impale seven men); huge ears; tough hide; ferocious disposition; shaggy brown hair; and inclined to drink great quantities of water. To kill it was a feat for a culture-hero of the stoutest mettle. There seems little doubt that such a description fits, of all things, the elephant or mammoth.

Until recently, there was no conclusive proof that man and mammoth were ever in contact with each other on this continent.[12] However, through excavation, archeologists were finally able to link him with an extinct species of huge bison and an extinct sloth, and in 1936 a gravel pit was opened at Clovis, N. Mex. Here were found mammoth bones and, under the bones, Folsom points. J. L. Cotter completes his report with, "The contemporaneity of deposition of these artifacts cannot be doubted."[13] In other words, man and mammoth were associated at one time on this continent.

Of course, it can be argued that if this were a story based on fact, then if we could show the Indians the remains of a mammoth they would recognize it as the beast of their stories. Unfortunately this has not proved to be the case. Natives of the Parma River when shown the skeletal remains of a mammoth expressed the opinion that they were the bones of a giant burrowing rabbit whose

[10] HEWITT, J. N. B., Bur. Amer. Ethnol. Archives, Smithsonian Institution, Hewitt MSS: Folder 445; obtained through the courtesy of Dr. W. N. Fenton and Anthony Wallace. Another Naked Bear story appears in JESSE CORNPLANTER'S *Legends of the Longhouse:* 104–137. Philadelphia, 1938.

[11] SWANTON, J. R., *Indian tribes of the lower Mississippi Valley and adjacent coast of the Gulf of Mexico.* Bur. Amer. Ethnol. Bull. 43. 1911.

[12] The reasons for this are easily explained. In the first place, early man in this country was not the picture writer that his European contemporary was. Further, except for a few isolated spots such as are found in the Southwest and the high plateau regions, this country seems peculiarly unsuited to the preservation of prehistoric remains, and ancient man, being nomadic, did not use the caves to the extent that the Europeans did. Of course, it would be difficult to connect him with any animal, let alone one particular beast.

[13] COTTER, J. L., *The occurrence of flints and extinct animals in pluvial deposits near Clovis, New Mexico: Pt. LV, Report on excavation at the gravel pit.* Proc. Acad. Nat. Sci. Philadelphia **89:** 15. 1937.

smaller kinfolk still abound in the region.[14] According to Ezra Stiles, when the skeletal remains of a mammoth were exhumed in Connecticut in the eighteenth century, Indians remarked, "You would not believe us when we told you the devil was killed here." However, this is hardly surprising. Skeletal remains do not resemble the living creature, and it is fairly probable that they would not have recognized the whole carcass.

It is, I think, significant to note that when mammoth bones were found in Europe they were thought to be the bones of everything from giants to saints, but the idea that they were the bones of an extinct animal was not considered until comparatively modern times. And it was the ancestors of these people who painted pictures of mammoth hunts on cave walls.

At this point it would be well to return to a remark made earlier concerning *ipso facto* myths. In both China and Siberia there are numerous remains of the mammoth to be found. In the latter region frozen carcasses have been found embedded in glacial ice when a spring freshet or some other natural phenomenon exposed them to view. Natives in both regions who saw the remains naturally tried to explain the phenomenon. They found only the dead creatures, and these carcasses were buried in the ground. How could this be? Obviously, they thought the creatures lived underground. Why couldn't one be caught alive? Because they were vulnerable to light and air and died instantly upon being exposed thereto. Thus, in Siberia the mammoth was referred to as a giant mole, and in China he is called "yen-men," burrowing ox. In none of these legends do we hear of stiff legs, a waving trunk, or their capacity for drinking water, nor is any great emphasis placed on their ferocious disposition. Obviously the stories told about them have been fashioned to fit the monster in his present state, just as was done among Indians of this continent who called the bones those of the devil or of a rabbit.[15]

We now come to the questions of how long legend can be retained without stimulus, and what was the date of departure of the mammoth from this continent.

During the seventeenth, eighteenth, and early nineteenth centuries we find many dissertations attempting to prove, first that the mammoth did exist in some remote part of the country, and later that the bones were more or less contemporaneous with the white men's coming. There are stories about finding the sinews, the arteries, the stomach, and a host of other perishable parts among the osseous remains. There are stories about finding mammoth hair in a bog. In one instance the Indians who brought in bones of a mammoth stated that they had seen the beast's head with a long nose and the mouth underneath. Thomas Jefferson and others reported that there were, at that time, some of these great monsters living far away in the wilderness. All of which, if true, would be convincing evidence of a late extermination of the creatures in question.

However, in all these stories there have been flaws. The mammoth hair turned out to be a form of algae. The mammoth head described by the Indians could have been the skeletal remains of a mammoth head with the long tusk sockets protruding and looking—to the untutored eye—like the nostrils of the animal. These and other stories have, as Dr. Eiseley points out with great completeness, been proved fabrications, and as yet we have no evidence of extinction of these beasts more recent that the late Pleistocene age.[16]

In a forthcoming article Dr. Eiseley will give evidence as to why these stories were so prevalent up to almost the present century. It seems that theology and science in the eighteenth century came to a sort of understanding. The Bible stated that all creatures were preserved on the ark, the clean animals in sevens, the male and his female and the unclean animals in twos, the male with his female to repopulate the earth.[17] The clergy argued that if this were the case and the Lord went to the trouble to preserve all creatures once, then it would be inconsistent of Him to allow some to perish from the earth. It

[14] TYLER, E. B., *Researches into the early history of mankind and the development of civilization:* 314. London, 1878.

[15] *Ibid.:* 311–320.

[16] EISELEY, L. C., *Men, mastodons and myth.* Sci. Monthly **62**: 517–524. 1946.

[17] Genesis 7: 2.

would, they felt, be an inconsistency in a constant being, that could not occur. Science went along with this idea and strove mightily to uphold it. When scientists saw the bones of the mammoth they tried to find evidence of recent death, and those who seek often find. When they heard the story of these beasts from the natives, they pressed the point of where they might be found. And the natives, to please the strange White Man, pointed vaguely off toward the unexplored and said, "There." Even Thomas Jefferson believed this idea and expressed the opinion that it was impossible for such creatures as Behemoth to be extinct. With this attitude he was more than grateful for any slight glimmer of hope that somewhere, in the land over the hill, the beasts might be found.

As to how long the memory of man can retain items is a question. The impact of the story has a great deal to do with the retention. The vehicle in which it is kept also has a lot to do with it. For example, stories connected with religion usually last longer than stories for story's sake. The Jews have kept their legends fresh for at least 4,000 years. But that is a written, not oral story. However, when a comet struck the Arizona desert 4,000 or 5,000 years ago some primitive people saw the literally earth-shaking event and today the account of this incident is to be found in the sun dances of their descendants. This is established fact. In New Brunswick the Malecite will tell you that at one time the St. John River ran uphill until a culture hero Mekumwesu made it go the other way. It is possible that this legend refers to a time when the St. John had not broken through the Falls of St. John. If so, this is in the thousands-of-years-ago era. In the north we are told that it once grew very cold and never warmed up. The land was covered with ice and snow, and the game disappeared until the condition was rectified by a culture-hero. This could refer to the ice age. It could also be a romanticized idea of summer. In the Amazon region there are myths concerning a large red-faced monkey that fits none of the monkeys living in South America today. However, there once was, in post-Pleistocene times, a large primate of this type in South America.[18] Although only the tale of the comet has been definitely proved of antiquity, the others smack strongly of beliefs dating from the last glaciation.

Although this paper deals primarily with the stiff-legged motif, it has been necessary to include other stories that we might more clearly round out the picture of the beast under discussion. From the description given, we find we have a creature strongly resembling only one thing—the mammoth. That this story is an importation from Europe is, from the evidence, improbable for the following reasons: (1) The stories relating to the mammoth are too widely scattered to be of white origin. (2) The stories differ widely among themselves, some lacking the stiff-legged motif entirely and, except that they describe the same animal, lacking the patterns one would expect in a myth with a common source. (3) When some of these stories were first related they contained much physical description that the European tale lacked entirely and that could hardly be called embroidery.[19] (4) These descriptions fitted what we know today to be the physical appearance of the mammoth, and when these stories were first told the white man did not know of the mammoth and therefore would not have described him. Thus, we are brought to the conclusion that the Indian must have remembered such a beast at one time in the ancient past. Furthermore, since no evidence has been brought forth to show that the mammoth existed after the Pleistocene age, we must consider that this memory dated back to that time. Without physical evidence to prove it, we dare not date the mammoth later.

[18] TYLER (*op. cit.*) points out that remains of a large post-Pleistocene monkey have been discovered. However, he feels that, since the monkey stood only about 4 feet high, the tale may still have validity in referring to some yet larger creature.

[19] It is important to note that the Indian version of this myth differs widely from the European version. In Europe, we have a paucity of physical description and a host of peculiar attributes such as being able to talk, producing young only when standing in ice water, fear of mice, and a sort of mutual-aid society that assisted the fallen to rise. If this were an imported story, it seems strange that all these trappings were deleted. The Indian, on the other hand is strong in his physical descriptions that, for the most part are not to be found in any of the European variants and, in fact, were unknown to Europeans until modern times. This, more than any other fact, would seem to substantiate the claim for a separate origin in this country.

There are only two more questions to be discussed, and they are the stiff-legged motif and why the myth continued to exist. Both of these can be answered simply. The taking of a beast such as the mammoth with nothing but spears, as supposed by some archeologists, must have been a titanic event. It would have been an epic struggle each time it occurred. Also these creatures did not become extinct overnight. As they diminished in numbers the taking of them became more and more of an event, until toward the close of their career it would prove to be the battle of a generation. As to the stiff-legged motif, that too is simple. The cylindrical quality of the leg and the shuffling walk would lead the untutored to suspect lack of articulation, which in turn, after physical contact with the mammoth had been lost, would point to the following rationalizations: (1) That such a beast would be unable to arise, if he once lay down, and (2) that he had jointless legs because of their shape and the shuffle. However, all things must sleep, and to sleep they must lie down. But, this animal cannot lie down; therefore he leans against a tree for support. Weaken the support and down comes mammoth, tree, and all.

Perhaps, if we allow ourselves to shake from our shoulders the weight of opinion that the majority of folklore among North American Indians is of foreign origin[20] and consider it in relation to man in prehistoric times, we can aid in pushing the date of man in North America closer to its birthday and at the same time throw some light on his activities before the dawn of recorded history. Legend today is not much help because it is adulterated by outside influence and destroyed by modern interests, but the legends recounted by the early writers on this continent throw a glimmer of light on a vast quantity of folklore only scraps of which have been recorded and less of which has been subjected to modern scholarship. It is well worth remembering that a German groceryman read a fairy tale, believed it, and discovered a civilization.

[20] Though some scholars try to tie Indian folklore into European sources, others like Tyler attempt to show contact with eastern peoples before the white coming. Through myth parallels, as we have seen in the case of the burrowing motif contained here, similar stories, where conditions are similar, can spring up quite independent of one another. In the case of the mammoth we may eliminate eastern motifs, since the story does not appear to occur either in China or in Siberia, the natural path of a people migrating to North America. Europe may be disqualified also as contributing much along these lines for reasons already stated. Let us, at least, consider the thought that where a people are in contact with a creature like the mammoth such stories may arise independently.

BIOLOGY.—*An adventure in biblio-chronology.*[1] RICHARD E. BLACKWELDER, U. S. National Museum.

The determination of the actual date of publication of works on taxonomic subjects is of great importance to the study of taxonomy because of the importance that has been placed on priority of publication. It is essential to know accurately the date of publication of the part of any work in which any new biological entity is proposed.

Many different means have been employed for determining the true dates of publication of such works. Because of this, these methods themselves become of interest to taxonomists and bibliographers. The following is an account of the means that were applied to the dating of one work. In this particular case the work has little taxonomic significance, so that the value of the determination of the dates lies principally in its illustration of the methods.

In the Zoological Record for 1907 there is listed a work by A. Heyne and O. Taschenberg entitled *Die exotischen Käfer in Wort und Bild*. Upon obtaining a copy of this quarto volume from the library, we find that it consists of 262 pages of text and 39 beautifully colored plates of beetles. The title page is dated 1908, the Vorwort (Preface) is dated 1907, and no other indication of date or serial issuance appears. From this we would conclude that the Vorwort was written in 1907 and the entire work published in 1908.

If, however, the copy we examined was bound in a library where original covers are preserved, then we might expect that if the

[1] Received April 19, 1949.

TABLE 1

1	Dates			Included pages			
	2	3	4	5	6	7	8
Lieferung or part number	Cover	Archiv für Naturg.	Reviews	Covers	Signatures	Archiv für Naturg.	Reviews
1	1893	(1893)*			1–6		
2	1894	(1894)			7–10		
3/4	1895	1895			11–26		
5	1896				27–34		
6	1896				35–42		
7/8	1897*	1897/1898*	1897/1898		43–58		43–58
9	1900	(1900)	1900		59–66	59–66	59–66
10	1901	(1901)	1901		67–74	67–74	67–74
11/12	1902	(1902)	1902	(74–90)	75–90	75–90	
13/14		(1903)	1903		91–106	91–106	
15/16		1904	1904		107–122		
17/18	1904	1904		(123–146)	123–138		
19/20	1905	(1905)	1905	(147–184)	139–170	141–170	
21/22	1906	1906		(171–195)	171–194	(24 pp.)	
23/24	1907	1907		(195–218)	195–218		
25/26	1907	1907		(219–262)	219–262		
27	1908*	1907	1907		Index, etc.		

* See discussion.

work appeared in parts we should find the covers bound in. These covers might provide more accurate dates. In the *Exotischen Käfer* in the Library of the U. S. Department of Agriculture there are 17 covers bound together at the back of the volume. They prove that this work appeared in 27 parts from 1893 to 1907 (some of the covers containing two parts). Presumably some pages of text and some plates appeared in each part, but in most cases no clue is given to what pages and plates were included. Since the dates on the covers show that the parts were published about a year apart, we have gained nothing unless we can determine the contents of each part as well as its date.

Several lines of investigation can yield clues to the contents of the parts and their dates of issuance. The results of each of these are shown in Table 1 for each of the 17 parts, as explained below. Certain general facts aid in interpreting these clues. Plates, being printed as separate sheets, can be issued in any order or in any quantity desired; e.g., part 1 might include plates 1 and 2, or plates 1 and 10, or plates 1, 2, 3, and 4. Text pages, on the other hand, are always printed in groups called signatures. These may be 16 or 32 pages folded together, or they may be fewer pages, but always an even number and never less than 4 except at the end of a work where a single sheet (2 pages) may possibly be used to accommodate the last part of the text. Therefore, one part of a serial publication always contains one or more signatures, and it is impossible for a signature to be divided between two parts. It is often possible to identify signatures by the folding of the sheets.

In the work at hand there are three sets of facts to be determined. These are the publication date of each part, the pages published in each part, and the plates published in each part. Taking the dates first, we examine the text of the work to see if there is any *statement* of the arrangement of the parts and the dates of them. Since there is none in this case, we turn to the covers. It is at once apparent that there are two kinds of covers, ones with number *and* date printed on them, and ones without date and with the number written in by hand in a blank provided therefore. The latter appear to be extra covers made up later when the regular stock ran out. If this is true, some other copy of the work might have all the original covers. Our bound copy has 13 of these originals, and we obtain another copy (unbound and incomplete) that has one additional one.

TABLE 1 (*Continued*)

Included plates								
9	10	11	12	13	14	15	16	17
Covers	Number of pls	Publisher of cover	Publisher of pls.	Plates referred to in text	Archiv für Naturg.	Reviews	Broken alike	Left over
	2	K	K	1			1,16	
	2	K	K	1,2			2,17	
	4	K	K	2,3,4			3,4,6,7,	
	2	R	D	4			5,9	
	2	R	D	4,5			8,10	
	4	R		5,6,7,8,9		11,12,13,14		
	2	(O)	O	9,10	15,19	15,19		
	2	O	O	10,11		18,20		
22,23,33,35	4	B	B	11,12,13	22,23,33,35			
	4		B	14,15,16,17,18,19	(4 pls.)			21,21^{bis},24,25
	4		B	18,19,20,21,21^{bis}		(26,27,28,29)*		
30,31	2		B	22,23,24				
32,34	2		B	22,23,24,25,2$\frac{1}{2}$		(32,34)		
36,37	2		B	26	(2 pls.)			
38,39	2		B	26,27,28				
None				28,29				
None								

Referring to Table 1, we take up each source of evidence and record the information obtained.

COLUMN 1. The covers are imprinted with the "lieferung" or part number. This enables us to identify the double numbers and the total number of parts.

COLUMN 2. Each cover is dated, with the exception of numbers 7/8, 13/14, 15/16, and 27. No. 7/8 is dated on another copy, and No. 27 included a title page which was dated.

Another way in which clues may be obtained from the work itself is by examining the notations that usually appear at the bottom of the first page of each signature. These sometimes include a date, but we are not lucky this time, for there is no notation at all.

With internal evidence insufficient, we must seek clues elsewhere. First we try the abstracting journals. The Zoological Record for 1907 contains a notice of the final part and implies that it was published in 1907. No earlier volumes mention the work at all.

COLUMN 3. Each year the Archiv für Naturgeschichte publishes a volume on the entomological publications of the preceding year. This work is cross-indexed by listing under each work the reviews of it in other works. Fifteen parts of the *Exotischen Käfer* are listed in the years 1893 to 1908. The year of publication is either stated or implied for each of these 15. (Dates not directly cited but clearly implied are in parentheses.)

COLUMN 4. The reviews listed in the Archiv für Naturgeschichte mention seven parts, giving dates either directly or by implication. No other reviews have been found.

We have now supplied dates for every part, with 10 of them verified by more than one source. In the case of No. 7/8 the date is given in two reviews as 1897/1898. Since the cover is dated 1897, it appears best to accept that. In the case of No. 27, the title page is dated 1908. Two journals list this part among the works appearing in 1907, so that we may assume that it appeared earlier than was expected, in 1907 rather than 1908.

Many of these same sources can be used for finding clues to the pages and plates included in each part. First of all we should search for a copy still in the original covers. Both the bound and the unbound copies available in this case have had the text and the plates rearranged, although the covers were not destroyed. We therefore get no direct indication of arrangement and must continue our search.

COLUMN 5. We start with the covers. On six of these we find a list of the families dealt with. This is an indefinite clue since the

families nearly always overlap the signatures.

COLUMN 6. Next we examine the text pages themselves. We find that they were printed in 17 groups of pages (signatures) ending on the following pages: 6, 10, 26, 34, 42, 58, 66, 74, 90, 106, 122, 138, 170, 194, 218, 250, and 262. The last two appear to have been in one part, and part 17 contained only index and new title page and introduction. Thus the signatures identify the pages issued in each part. (These conclusions are verified in later columns.)

We have now identified all the page groups, but to check these, and to show further methods, we shall see what other indications we can find.

COLUMN 7. The Archiv für Naturgeschichte references to this work cite the pages included in five parts and state that another part contains 24 pages.

COLUMN 8. The reviews in other journals cite pages for three parts.

Only one discrepancy occurs. The Archiv für Naturgeschichte cites pages 141–170 as belonging in part 19/20. The signatures show that this is an error for 139–170, since the signature break comes between 138 and 139. Thus all the pages have been assigned to their proper parts.

For the plates we can use these same sources as well as some others. It might well be assumed that the plates appeared in numerical order, in some fixed quantity per part. Evidence from the covers shows that this would be an error.

COLUMN 9. Certain covers carry a list of the included plates.

COLUMN 10. Before this copy was bound, someone made a notation on each cover of the number of plates included but did not specify which plates.

COLUMN 11. On the back cover of each part is a line identifying the printer. (An initial is used here, since we are interested only in the changes from one printer to another.) This column is inserted for comparison with column 12.

The plates carry no notations to identify the parts in which they appeared. They do have certain other clues that may help us.

COLUMN 12. Close examination of the plates shows certain differences in the type used for the legends. This and the imprint of the lithographer on each show that four different firms contributed to the making of the plates. The plates can thus be grouped according to the lithographer, with the following results: (1) plates 1, 2, 16, 17; (2) plates 3, 4, 6, 7; (3) plates 5, 8, 9, 10; (4) plates 11, 12, 13, 14; (5) plates 15, 18, 19, 20; and (6) plates 21–39. Each group of plates may safely be assumed to have appeared in one part or in adjacent parts. This column then shows the initial of the lithographer of the plates which our final conclusions show to belong to each part. (This is for comparison with column 11.)

We can thus see that plates 1, 2, 3, 4, 6, 7, 16, 17 were published in parts 1–4, since they are by the same printer; that plates 5, 8, 9, 10, 11, 12, 13, 14 were in parts 5–8; that plates 15, 18, 19, 20 were in parts 9–10; and that plates 21–39 were in parts 11–26.

COLUMN 13. It would seem reasonable that each plate should appear in the part in which it is first referred to, or in an earlier part. This column therefore lists the plates referred to in each part.

Looking now at the external evidence, since there is no specific indication on the plates to show where they belong, or in the text to show which plates appeared with each group of pages, we find several indications.

COLUMN 14. The citations in the Archiv für Naturgeschichte list the plates in parts 9 and 11/12, and state that part 13/14 has four plates and part 21/22 two plates.

COLUMN 15. The reviews listed in the Archiv für Naturgeschichte list the pages in parts 7/8, 9, and 10 and enumerate the families included on the plates of 15/16 and 19/20. From the latter we can identify the plates by examination.

We have now identified the plates of all parts except 1 to 6 and 13/14. For the former we have determined (in discussion of Column 12) that plates 1–10 and 16–17 must have been issued in the following groups: (1) 1, 2, 16, 17; (2) 3, 4, 6, 7; and (3) 5, 8, 9, 10. We assume that plate 1 appeared in part 1, and we then compare the four plates 1, 2, 16, and 17 for blemishes that would show up on two adjacent sheets, such as gluing or stapling marks, marginal tears or folds, and

differences in paper. We find at once that plate 1 has an injury that is matched on plate 16 only, and appears likewise on the cover of part 1 and the text pages 1–6. This definitely establishes the fact that part 1 contained plates 1 and 16. The same procedure definitely associates plates 2 and 17, plates 3, 4, 6, 7, plates 5 and 9, and plates 8 and 10.

TABLE 2

Lieferung	Pages	Plates	Date
1	1–6	1, 16	1893
2	7–10	2, 17	1894
3/4	11–26	3, 4, 6, 7,	1895
5	27–34	5, 9	1896
6	35–42	8, 10	1896
7/8	43–58	11, 12, 13, 14	1897
9	59–66	15, 19	1900
10	67–74	18, 20	1901
11/12	75–90	22, 23, 33, 35	1902
13/14	91–106	21, 21 bis, 24, 25	1903
15/16	107–122	26, 27, 28, 29	1904
17/18	123–138	30, 31	1904
19/20	139–170	32, 34	1905
21/22	171–194	36, 37	1906
23/24	195–218	38,39	1907
25/26	219–262		1907
27	Index, etc.		1907

Since all the plates except four have now been placed, these four must have belonged in part 13/14, the only one not yet settled. These all belong to one lithographer-group and are approximately in their normal place in the series. It is therefore not necessary to seek further evidence.

We now have determined, through one means or another, every fact which we set out to find. These are summarized in Table 2, where the date of each page and plate may be determined. However, we still have not exhausted the possibilities of this type of research. Some further lines of investigation are suggested below.

A very careful examination of the text might reveal references to recently published literature; these would definitely show that that page of the text was published later than the work cited. Or references to our particular work which appear in other works would show that those other works are more recent. If enough of these citations can be found they may give fairly accurate clues as to date of publication.

Many libraries make direct notations of the date of receipt. Others keep such details in their accession records. These will often prove that a work appeared before a certain date. These records will sometimes also demonstrate that a work appeared in parts and may even indicate the contents of each part.

Where the date of the work of a particular writer has been questioned, because of a conflict in the priority of names, the author himself or some other contemporary writer may have published statements giving details about the work in question. These are not always listed in reviewing journals, since they may be published as commentary in a work the title of which gives no clue to this commentary.

It can thus be seen that there are many lines of inquiry that may help us in determining the details of publication of a work. It is very important that details of this type should be made known, since in many cases priority of scientific names depends solely on the date of publication. We cannot stabilize the names until we know (or at least agree upon) the dates of their publication.

BOTANY.—*Studies in* Lonchocarpus *and related genera, V: New species from Middle America and the* Lonchocarpus guatemalensis *complex.*[1]

FREDERICK J. HERMANN, U. S. Department of Agriculture.

Continued investigations of available Mexican and Central American collections of the *Lonchocarpus* group has necessitated the recognition of the following novelties and realignments.

Terua Standley & Hermann, gen. nov.
Leguminosarum

Frutex vel arbor parva ramis alternis; folia alterna, imparipinnata, stipulata; foliola opposita, exstipellata, integra, plus minusve punctata; paniculae 1–3 axillares; corollae alae carinae adhaerentes; stamen vexillare ima basi liberum, medio cum caeteris in tubum clausum connatum; legumen compressum suturis incrassatis, sutura ventrali dehiscens; semina 1–4, subreniformia, hilo armillato.

Shrub or small tree with alternate branches; leaves alternate, imparipinnate, stipulate, glabrous; leaflets opposite, exstipellate, irregularly translucent-punctate, the nerves (except the midrib) not impressed, the margins entire; flowers borne on axillary peduncles; calyx at maturity broadly cupuliform (urceolate in the bud); wings of the corolla strongly adherent to the apical half of the keel; stamens monadelphous, fenestrate, the basal 2 mm of the tenth stamen free; anthers two-celled, versatile, lanceolate; style arcuate; stigma minute, terminal, glabrous; legume strongly compressed, stipitate, both sutures thickened, 1–4-seeded, elastically dehiscent along the ventral (vexillar) suture; seeds subreniform, compressed, the hilum surrounded by a membranaceous ridge.

A single species is known, native to the valley of the Río Yeguare, Honduras. Because of its dehiscent pods it must be referred to the tribe Galegeae rather than to the Dalbergieae (characterized by completely indehiscent legumes) with which it has very close affinity in most other respects. It appears, indeed, to be a more markedly transitional type between the two tribes than any genus so far known. Its mimicry of *Lonchocarpus* is striking in such features as the adherence of the wings of the corolla to the keel and the clearly punctate young leaves (the translucent cells, however, tending to plug up and become opaque with age). Other lonchocarpoid characteristics, such as the conspicuous resin-blisters on calyx and corolla, the rugose, vermiculate petiolules, and monadelphous, fenestrate, stamen-tube (a structure common in the Phaseoleae and some of the Galegeae but in the Dalbergieae known only in *Lonchocarpus*, *Derris* and *Piscidia*, as pointed out by Bentham) are shared by a few genera of the Galegeae such as *Willardia*. *Terua* clearly falls nearest to *Willardia* in the Galegeae but differs from it in having the wing petals strongly adherent to the keel, the claw of the standard appendaged at the base, pods without resin-ducts, and seeds with the hilum bordered by a membranaceous collar. The genus is dedicated to Terua Williams (Mrs. Louis O. Williams), of the Escuela Agrícola Panamericana, Tegucigalpa, Honduras.

Terua vallicola Standley & Hermann, sp. nov.

Arbor gracilis (4–6 m) vel frutex (2–4 m); stipulae inconspicuae; folia 5-foliata; petioluli exstipellati, vermiculati, rugosi; foliola late elliptica vel oblongo-ovata vel ovato-lanceolata, 1.8–10 cm longa, 0.8–5 cm lata, subcoriacea, apice obtusa vel emarginata, basi obtusa vel acuta marginibus aliquantum revolutis; paniculae folia subaequantes; flores 11–14 mm longi, glabri, subtiliter nervati et canalibus resinosis dense maculati; calyx 2.5–3 mm longus maturitate 4–6 mm latus dentibus brevissimis vel obsoletis; vexillum obovatum, 11 mm longum, 9 mm latum, basi subauriculatum apice profunde emarginatum, ungue basi apendiculato; legumen ellipticum (ca. 4 x 2.5 cm) vel irregulariter oblongum (ca. 8 x 2 cm) vel lineari-oblongum (ca. 7 x 1.5 cm), apice acuto vel mucronato, coriaceum, glabrum.

Slender tree or tall shrub, 2–6 m high, with terete glabrous branches thickly dotted with stramineous lenticels; stipules rudimentary, scale-like, broadly ovate; leaves 5-foliolate, 7–15 cm long, the petioles 1.5–3 cm long, glabrous, the rachis and upper part of the petiole (terete at the base) deeply canaliculate; petiolules exstipellate, 2–3 mm long, vermiculate, strongly cross-wrinkled, shallowly canaliculate above; leaflets broadly elliptic to oblong-ovate or ovate-lanceolate, 1.8–10 cm long, 0.8–5 cm wide, subcoriaceous, the apex obtuse to emarginate, rounded to abruptly tapering at the base, 4–7 of the second-

[1] Received March 24, 1949.

ary nerves prominent especially beneath, the margins somewhat revolute; panicles 5–10 cm long, about equaling the leaves, loosely few-flowered, the primary peduncle 1–3 cm long, secondary peduncles 3–7 mm long, with a minute (0.5 mm) ovate bract at the base, pedicels 2–3 mm long, bearing a blunt to acute, ovate bract (0.5 mm) at their base and a pair of frequently larger (0.5–1 mm), narrowly ovate bractlets about 1 mm below the flower; flowers 11–14 mm long, dark red-purple, finely and conspicuously nerved and thickly dotted with resin-ducts; calyx 2.5–3 mm long, 4–6 mm wide, more or less plainly dotted or lined with resin ducts, glabrous without except for the minutely ciliolate margin, the apical third strigulose within, the teeth very shallow or obsolete though generally prominent in the bud; standard obovate, 11 mm long, 9 mm wide, subauriculate at the base, deeply emarginate, glabrous, the center dark green, the short claw (1.5 mm) with an inverted U-shaped appendage near the base; wings with a claw 2 mm long and an oblanceolate blade 8 mm long, 2.5–3 mm wide, glabrous; keel 8.5 mm long (blade 6.5 mm, claw 2 mm), the basal half free from the wings, white-sericeous toward the apex; stamen-tube and the free portion of the filaments glabrous; ovary sericeous along both margins; style more or less ciliate along the upper margin, frequently also along the lower; legume elliptic (averaging 4 x 2.5 cm) to irregularly oblong (averaging 8 x 2 cm) to linear-oblong (averaging 7 x 1.5 cm), light brown, glabrous, coriaceous, attenuate to abruptly rounded and stipitate at the base, the apex abruptly acute to mucronate; seeds 1–4, dark reddish brown, subreniform, glossy, 6–8 mm long, 9–12 mm wide, the hilum oval, 1.5–2 mm long, surrounded by an irregular, translucent, orange-yellow collar.

HONDURAS: DEPT. EL PARAÍSO: In barranca along Río Yeguare near Las Casitas, alt. 900 m, Dec. 4, 1946, *L. O. Williams & A. Molina R. 11072* (F—type); in quebrada along creek near Las Casitas, alt. 850 m, Jan. 5, 1947, *L. O. Williams & A. Molina R. 11532* (F); scrub forest near Las Casitas, alt. 850 m, Nov. 16, 1947, *L. O. Williams & A. Molina R. 13414* (F); rocky stream bank, vicinity of Galeras, 800–900 m, Jan. 5, 1947, *Standley et al. 1991* (F; USNA); oak forest on Montaña de Yuscarau, alt. 2000 m, Dec. 7, 1947, *A. Molina R. 602* (F). DEPT. MORAZÁN: along junction of Gallo and Jicarito Creeks, Jicarito, alt. 1000 m, June 19, 1947, *A. Molina R. 145* (F); grassy slopes in pine forest near San Antonio, alt. 1200 m, July 17, 1947, *A. Molina R. 336* (F); dense moist forest, Quebrada Seca, on road between El Zamorano and San Antonio de Occidente, alt. ca. 900 m, Aug. 5, 1947, *Standley 11745* (F; USNA).

Lonchocarpus lasiotropis, sp. nov.

Arbor 7–30 m; stipuli acerosi, strigosi, 6 mm longi; folia 13- (interdum 11- raro 9-) foliata; foliola elliptico-lanceolata, acuminata, chartacea, epunctata; inflorescentia terminalis, paniculis racemiformibus laxifloris; pedicelli 3–3.5 mm longi, fulvo-strigosi bracteolis duobus lanceolatis medio praediti; flores 10–12 mm longi; calyx cyathiformis dente carinali (1–1.5 mm longo) deltoideo-acuminato insigni; vexillum extus uberrime sericeum; alarum auriculae pusillae; carinae petala semiorbicularia spisse sericeo-strigosa trichomis rigidis albis ensiformibus 0.75 mm longis margine inferiore fere ubique connata; fenestra basi columnae filamentarum 1 mm longa, 2 mm lata; ovarium 6–7-ovulatum; legumen ignotum.

Tree 7–30 m high, up to 75 cm in diameter, with terete glabrescent branches thickly dotted with prominent lenticels, the branchlets strigose to strigose-puberulent; stipules semipersistent, narrowly linear to awl-shaped, 6 mm long, 1 mm or less wide at the base, strigose without; leaves generally 13-, sometimes 11-, rarely 9-foliolate, 14–29 (averaging 23) cm long, the subterete petiole 4.5 (3)–5.5 cm long, this and the canaliculate rachis more or less strigose, the latter usually densely so; petiolules 3–5 mm long, strigose or hirtellous, dark brownish green, rather shallowly canaliculate above, frequently parasitized and then tubercled; leaflets stiffly chartaceous, elliptic-lanceolate, the blade 4–10 cm long, 1.75–4 cm wide, dark green and glabrous or sparsely strigose above, paler and strigose beneath, epunctate, the apex acuminate, the base acute or somewhat rounded, lateral veins about 15 pairs, stramineous, very prominent especially beneath; inflorescence terminal, the panicles 10–15, racemiform, loosely flowered, 5–14 cm long; primary peduncle subterete at the base, angled above, more or less appressed-puberulent, floriferous to within 1–2 cm of the base; secondary peduncles 0.5–1 mm long, strigose, two-flowered; pedicles 3–3.5 mm long, tawny-strigose, the caducous bractlets lanceolate, 1.5 mm long, strigose, attached midway on the pedicel; flowers 10–12 mm long, "pinkish to lavender" (Yuncker et al.); calyx cyathiform, rigid-chartaceous, 3 x 5–6 mm, densely tawny-strigose, the upper teeth almost obsolete, the lateral min-

ute (0.5 mm), the carinal prominent (1–1.5 mm), deltoid-acuminate; standard obovate-orbicular, 11–13 x 10–11 mm, copiously sericeous-strigose without, glabrous within, emarginate and slightly cucullate at the apex, tapering to the short auricles at the base, the claw (2.5 mm) thickened, extended as a short (0.25 mm) callous above each auricle; wings 13 mm long (the claw 4 mm), 4.75 mm wide, oblique-oblong, the vexillar margin elevated at the base and very slightly prolonged forming a short auricle, long-sericeous without along the median line, adnate to the keel near the base; keel petals 12.5 mm long (the claw 4.5 mm), 4.5 mm wide, semiorbicular, their lower margins united from just below the apex to within 2 mm of the claw, copiously sericeous-strigose with long (0.75 mm), stiff, white, flattened trichomes; stamens monadelphous, glabrous, the tube broadly fenestrate at the base, the vexillar stamen free only at the opening (1 mm) and there much broadened; anthers versatile, two-celled, broadly elliptic, 0.4–0.5 mm long; ovary compressed, linear, sessile, densely white-strigose; ovules 6–7; style glabrous; stigma capitate; pod unknown.

HONDURAS: DEPT. OF ATLANTIDA: Solitary in open grassland near the Cangrejal River, foothills back of Ceiba, July 29, 1938, *T. G. Yuncker, J. M. Koepper, & K. A. Wagner 8670* (F; US—type); wet thicket near Tela, Lancetilla Valley, alt. 20–600 m, Dec. 6, 1927–March 20, 1928, *P. C. Standley 55495* (F; US); DEPT. OF YORO: farm 43, near Progresso, Apr. 16, 1929, *W. D. Hottle 88* (F). All three collections were distributed as *L. michelianus* Pittier. Only the type collection is in flower.

Vernacular name: "Cincho."

Closely related to the Venezuelan *Lonchocarpus margaritensis* Pittier, from which it differs in its more numerous (13 rather than 7), acuminate, strigose (rather than velutinous) leaflets, terminal inflorescence, copious vesture of the keel (the trichomes in *L. margaritensis*, too, are less than 0.5 mm long, terete and softer) and short, broad opening (2 mm wide) in the stamen-tube (in *L. margaritensis* the opening is narrow and fully 2 mm long). Among the Middle American species, *L. orizabensis* Lundell (*L. affinis* Pittier, non Wildem.) is perhaps nearest *L. lasiotropis* but that species is at once distinguishable by its conspicuously impressed-nerved leaflets and its densely flowered, spiciform panicles with ferruginous-villous indument, filiform bractlets and small flowers.

Lonchocarpus venustus, sp. nov.

Arbor 6–10 m; folia 5–7-foliata, 20–30 cm longa; petioluli 8–10 mm longi dense puberulenti; foliola ovata vel ovato-lanceolata, 5–16 cm longa, conspicue punctata; paniculae 2–4, axillares, spiciformes densifloraeque; pedicelli 2.5–3 mm longi, strigosi; flores 10–12 mm longi; calyx cupuliformis margine undulata; vexillum late orbiculare; basi auriculatum margine involuta; alae obliquo-oblongae; carinae petala margine inferiore per dimidium terminale connata; ovarium 6–7-ovulatum; legumen ignotum.

Tree 6–10 m high, 25 cm in diameter, with "slippery gray bark" (Alexander and Hernández) and terete, glabrous branches; stipules small (1 x 2 mm), broadly ovate; leaves 5–7-foliolate, 20–30 cm long, the terete, often somewhat striate petiole (4–6 cm long) and subterete or slightly canaliculate rachis appressed-puberulent, becoming glabrate; petiolules 8–10 mm long, densely puberulent, canaliculate toward the blade, generally more or less rugose (especially that of the terminal leaflet) at least beneath; leaflets rather thick- or leathery-chartaceous, abruptly acuminate to (rarely) acute at the apex, conspicuously pellucid-punctate, glabrous above, densely appressed-puberulent becoming glabrate beneath, the 6–8 pairs of lateral veins prominent beneath, the lateral leaflets unequally ovate to ovate-lanceolate, the blade 5–11 cm long, 2.8–6 cm wide, the inner side rounded at the base, the outer cuneate, the terminal leaflet elliptic-ovate, the blade 10–16 cm long, 6–8 cm wide, cuneate at the base; panicles 2–4, axillary, spiciform, densely flowered, 22–32 cm long, the primary peduncles striate at the base becoming sharply angled above, rather sparingly appressed-puberulent, floriferous for three-fourths of their length; secondary peduncles 2 mm long, two-flowered, strigose, crowned with a pair of minute (0.5 mm), ovate, strigose, caducous bracts; pedicels 2.5–3 mm long, strigose, bearing a pair of subulate, strigose bractlets (1 mm long) at or below the middle; flowers 10–12 mm long, "light rose-lilac, with a white spot [at base of standard?], very fragrant" (Alexander and Hernández); calyx cupuliform, 3 x 4–5 mm, sparsely strigose, the lower half yellowish green and frequently purple-spotted, the terminal half cinnamon-brown, the margin undulate, the teeth (except the deltoid carinal tooth, 0.5 mm long) almost obsolete; standard broadly orbicular (12 x 13 mm), sericeous without and in the center and

along the median longitudinal axis within, deeply emarginate, involute at the auriculate base forming crests or flaps 1 mm high on the inner margins of the auricles, the claw 2 mm long; wings 11–12.5 mm long (the claw 4.5 mm), 5 mm wide, oblique-oblong, auriculate at the base on the vexillar margin, sericeous without along the median line, adnate to the keel near the base; keel petals 11.5 mm long (the claw 4 mm), 4.5 mm wide, their lower margins united for the terminal half, conspicuously lineate and minutely sericeous; stamens monadelphous, glabrous, the tube fenestrate at the base; anthers two-celled, versatile, elliptic, 0.75 mm long; ovary linear, somewhat compressed, sessile, densely short-sericeous; ovules 6–7; style ciliate along the lower margin; stigma capitate; pod unknown.

MEXICO: GUERRERO: Chilpacingo to Iguala, Aug. 11, 1945, *E. J. Alexander and E. Hernández Xolocotzi 151* (USNA—type: USNH); MEXICO: Large tree, Bejucos, alt. 610 m, Dist. of Temascaltepec, Aug. 26, 1932, *G. B. Hinton 1473* (F); Limones, Dist. of Temascaltepec, Aug. 16, 1935, *G. B. Hinton 8179* (F). Both Hinton collections were distributed as *L. guatemalensis*.

Vernacular name: "Palo de Aro."

Lonchocarpus venustus has characteristics in common with *L. michelianus* Pittier, *L. malacotrichus* Harms, and *L. caudatus* Pittier. From the first of these it is readily distinguished by its elongate, densely-flowered panicles, its short secondary peduncles (2, rather than 4–5, mm long) and pedicels (2.5–3, rather than 6–7, mm long), and its fewer and much larger leaflets. Distinctions from *L. malacotrichus* are more difficult to give with certainty because that species is still known in this country only from the description and a fragment of the type specimen. The latter shows the presence of large bractlets at the base of the calyx which are not present in *L. venustus*, and the vesture of an apparently rather young leaflet is densely villous rather than appressed-puberulent. Furthermore the leaflet does not seem to be punctate, as described, although groups of cells here and there are translucent owing to insect or fungus attack. No flowering material of *Lonchocarpus caudatus* is yet known; hence the difficulty of comparing it with the present species of which the legume is unknown. The punctate leaflets of *L. venustus* should set it off readily enough from *L. caudatus*, but it is questionable whether the latter species actually is epunctate or whether puncta which may have been pellucid in the young leaves have become filled by some opaque secretion with age, this being the impression obtained when the leaflets are examined by intense transmitted light. The general shape of the leaflets, the relative lengths of petioles and petiolules and the unusually stout axillary primary peduncles are very similar in the two species. The leaves are much more nearly glabrous in *L. caudatus* than in *L. venustus*, the leaflets more coriaceous (nor do they show the cuneate base which prevails in the outer half of the lateral leaflets of *L. venustus*) and the pedicels longer (5 mm); but until these three plants are all known in their complete seasonal transformations their true relationship must remain in doubt.

Lonchocarpus resinosus, sp. nov.

Arbor 5 m; folia 5-foliata; foliola ellipticо-lanceolata, punctata, margine per dimidium terminale crenulata; paniculae 3–6, axillares, racemiformes laxifloraeque; pedicelli canescentes bracteolis duobus squamiformibus supra medium praediti; flores 13–15 mm longi; calyx cupuliformis, coriaceus, resiniferus, margine subintegra; vexillum late orbiculare canaliculis resinosis purpureis maculatum, basi profunde cordatum; alae obliquo-oblongae; carinae petala margine inferiore solum medio connata; ovarium 5–6-ovulatum; legumen ignotum.

Tree 5 m high, 25 cm in diameter, with gray bark and terete, glabrous branches; stipules minute; leaves 5-foliolate, 19–26 cm long (the terete, glabrous petioles 5–7 cm long), the rachis shallowly channeled and sparsely puberulent above; petiolules 7–8 mm long, deeply rugose, canaliculate and faintly puberulent above; leaflets coriaceous, elliptic-lanceolate to slightly obovate-lanceolate, the blade 4.5–11 cm long, 2–6 cm wide, dark green above, much paler beneath, the apex acuminate to short-caudate, the base cuneate, pellucid-punctate, the resin-ducts occasionally much elongated, glabrous above and below except the midrib and sometimes the lateral veins sparsely short-pilose, the lateral veins 5–9 pairs, very prominent on both surfaces, the margin indurated, crenulate from below the middle to the apex; panicles 3–6, axillary, racemiform, loosely flowered, 4–17 cm long; primary peduncles terete at the base, becoming striate and finally strongly angled and canescent above, floriferous for about three-fourths of their length; secondary peduncles 3–4 mm long, canescent; pedicels 4–5 mm long, canescent, with a pair of scale-like bractlets (0.75

mm) above the middle; flowers 13–15 mm long, "purplish-rose, the spot greenish-white turning purple" (Alexander and Hernández); calyx cupuliform, coriaceous, 4 x 5–6 mm, minutely and sparingly strigose, heavily lined throughout with dark purplish brown resin-ducts, the margin ciliolate, subentire, a minute carinal tooth perceptible; standard broadly orbicular, 12–13 x 14–15 mm, finely sericeous without and in the center within, dotted with purplish red resin ducts, especially toward the deeply emarginate apex, deeply cordate at the base, forming long narrow, involute auricles equaling the claw (2 mm); wings 13.5 mm long (the claw 4 mm), 5 mm wide, oblique-oblong, the vexillar margin prolonged at the base and somewhat auriculate, very sparingly sericeous without along the median line, with conspicuous broken lines of resin-ducts, adnate to the keel near the base; keel petals 14 mm long (the claw 4.5 mm), 4.5 mm wide, falcate, obtuse at the apex, their lower margins united in the center but free at either end, heavily marked with broken lines of dark resin-ducts, minutely and sparingly sericeous; stamens monadelphous, glabrous, the tube fenestrate at the base, the vexillar stamen free throughout its lower half and the filament much broadened at the base; anthers versatile, two-celled, elliptic, 0.75 mm long; ovary linear, somewhat compressed, sessile, densely short-sericeous; ovules 5–6; style sparingly sericeous below, glabrate above; stigma capitellate; pod unknown.

MEXICO: GUERRERO: Cañon de los Sabinos, ca. 60 km west of Iguala, Aug. 9, 1945, *E. J. Alexander and E. Hernández Xolocotzi 63* (USNA-type; USNH).

Vernacular name: "Rosa morada."

Apparently related to *L. michelianus* Pittier, from which it is at once set off by its coriaceous, glandular-blotched calyx, its strongly auriculate standard, bractlets distant from the calyx, elongate, loosely-flowered inflorescence and fewer, larger, coriaceous, elliptic-lanceolate, prominently veined, crenulate leaflets.

Lonchocarpus spectabilis, sp. nov.

Arbor 7 m; folia 11–15-foliata, 21–30 cm longa, rhachi petiolulisque tomentosis; foliola elliptica vel oblanceolata, epunctata, utrinque molliter strigosa; paniculae 3–5, axillares, racemiformes; pedicelli 7–9 mm longi, tomentosi; flores ca. 2 cm longi purpurei vexillo macula albida; calyx cupuliformis vel cyathiformis margine truncata vel undulata; vexillum orbiculare abrupte auriculatum; alae cymbiformes; carinae petala margine inferiore connata; ovarium 4–6-ovulatum; legumen ignotum.

Tree 7 m high, with smooth gray bark and terete, densely puberulent branches; stipules small (1.5 mm long), broadly ovate; leaves 11–15-foliolate, 21–30 cm long, the petiole (5–6 cm long, subterete), rachis and petiolules (5–6 mm long) tomentose; leaflets rather stiffly chartaceous, elliptic or oblong-elliptic to oblanceolate, the blade 3.5–9 cm long, 1.5–3 cm wide (averaging 6.5 x 2 cm), the apex somewhat acute to obtuse, rounded to gradually tapering at the base, epunctate, softly strigose above and below, with about ten pairs of lateral veins which are prominent and puberulent beneath as is the somewhat impressed midrib on both surfaces; panicles 3–5, axillary, racemiform, 18–26 cm long, the primary peduncles terete, densely puberulent, floriferous for about half their length, the secondary 2–4 mm long 2-flowered, unevenly puberulent; bracts caducous, not seen; pedicels 7–9 mm long, tomentose, bearing a pair of filiform-subulate bractlets (1.25 mm long) above the middle; flowers averaging 2 cm (15–23 mm) long, when fresh "purple with a whitish spot on standard" (Alexander and Hernández); calyx cupuliform to cyathiform, densely appressed-puberulent, in anthesis 3 mm long, 8 mm wide, the margin truncate or somewhat undulate, the carinal tooth rudimentary, the others obsolete; standard orbicular (19 x 19 mm), sericeous without, glabrous within, emarginate, abruptly auriculate, the short claw (2.5–3 mm) thickened; wings cymbiform, 20 mm long (the claw 4.5–5 mm), 8 mm wide, sparsely sericeous along the center without, exceeding the keel and adherent to it toward the base; keel petals 17–18 mm long (the claw 5 mm), 7 mm wide, their terminal half united along the lower margin, conspicuously sericeous along lower margin especially toward the broadly rounded apex; stamens monadelphous, glabrous, the tube fenestrate at the base; ovary linear, compressed, sessile, densely sericeous; ovules 4–6; style slightly hirtellous along the upper margin; stigma capitellate; pod unknown.

MEXICO: GUERRERO: Taxco to Iguala, Aug. 3, 1945, *E. J. Alexander and E. Hernández Xolocotzi 3* (USNA - type).

Vernacular name: "Gallito."

Nearest allied to *Lonchocarpus orizabensis* Lundell (*L. affinis* Pittier, non Wildem.), from which it differs in its strikingly large flowers (fully equaling those of *L. megalanthus* Pittier, which have been the largest heretofore known in the

genus), the standard, wings and keel being 3 to 4 times the size of those in that species, in its rudimentary calyx-teeth and in its elongate pedicels (7–9, rather than 2–3, mm).

Lonchocarpus sinaloensis (Gentry), comb. nov.

Piscidia sinaloensis Gentry, Brittonia **6**: 316. 1948.

The paired flowers and rudimentary calyx teeth of this species, as well as its close similarity to *Lonchocarpus oaxacensis* and *L. megalanthus*, indicate that its position is properly in the genus *Lonchocarpus*.

The original description may be supplemented by the following diagnostic characters, taken from an isotype (*Gentry 5525*) and a paratype (*Gentry 5937*, distributed as *Brongniartia* sp.) in the National Arboretum Herbarium, since they become significant for the plant in its new position.

Petiolules 3 mm long, gray-puberulent, canaliculate above; leaflets coriaceous, pellucid-punctate, early glabrescent except along the veins; panicles about 12, axillary; secondary peduncles 3–5 mm long, terminated by two pedicels and a subulate, adaxial projection of the axis 1–1.5 mm long; bractlets suborbicular, 2 x 2.5 mm, densely sericeous; calyx teeth shallow in the bud, almost obsolete in anthesis; standard 15 mm wide, minutely but copiously sericeous without; wings finely sericeous along the median line and sometimes the basal half without, the blade 10–11.5 mm, the claw 6.5–7 mm long; keel petals united at the middle along their lower margin, sericeous without, glabrate within except near the lower margin; stamens monadelphous, glabrous, the tube fenestrate at the base, the margins of the opening thickened, the tube greatly broadened toward the base, the filament of the vexillar stamen widened at the base and free only at the opening (3 mm); anthers large (1 mm long), ovate, versatile but attached near the base; ovary sessile, linear, compressed, densely canescent; ovules 5.

The affinities of *L. sinaloensis* and the characteristics by which it is most readily distinguished from its nearest allies are indicated in the key to the *L. guatemalensis* group at the end of the following discussion.

LONCHOCARPUS GUATEMALENSIS AND ALLIES

One of the most natural groups within the genus is comprised of *Lonchocarpus guatemalensis* Benth., widely distributed in Middle America, and the plants proposed as *L. proteranthus* Pittier (Panama), *L. oaxacensis* Pittier (Oaxaca), *L. darienensis* Pittier (Panama), *L. dumetorum* Brandegee (for reference of this name to synonymy with *L. darienensis* cf. Journ. Washington Acad. Sci. **38**: 12. 1948), *L. megalanthus* Pittier (Nayarit to Michoacán), *L. mexicanus* Pittier (Veracruz), and *L. sinaloensis* (Gentry) Hermann (Sinaloa). In Pittier's systematic arrangement affinity is indicated between only three of the seven of these plants there treated; *L. proteranthus* is isolated in his section Punctati of subgenus *Eulonchocarpus*, *L. oaxacensis* is placed near the beginning of section Epunctati and *L. darienensis*, *L. megalanthus*, and *L. mexicanus* are grouped at the end of the same section, which also falls under *Eulonchocarpus*, while *L. guatemalensis* is assigned a place in section Carinati of the subgenus *Neuroscapha*. But the legumes in the type specimen of *L. proteranthus* do not have the vexillar margin "sharp-edged or rounded"; rather it is deeply and conspicuously concave (a characteristic already noted in the half-grown fruits of the type of *L. guatemalensis* by Bentham), though it is scarcely thickened. In this respect the pods resemble those of *L. hondurensis* and *L. lanceolatus* and the plant would therefore be referable to *Neuroscapha* with as much reason as are those two species, but at any rate it must be excluded from *Eulonchocarpus*. Fruiting material of *L. guatemalensis* and *L. megalanthus*, which was either unidentified at the time of Pittier's monograph or turned up later, is characterized by the same type of pods. The leaflets of all these entities are predominently pellucid-punctate (conspicuously so in the type collections of all except that of *L. oaxacensis* where the puncta are obscure except under very strong light), so that another supposed character for distinguishing between them is found to be untenable. Leaflet shape, one of the two bases for the segregation of *L. mexicanus*, is of doubtful diagnostic value, since the leaflets in typical *L. guatemalensis* alone vary from narrowly elliptic through lanceolate and ovate to almost orbicular. *Lonchocarpus megalanthus* and *L. guatemalensis* are sometimes proteranthous and sometimes not. There appears to be no reason for assuming that others of the group are any more constant in this respect.

Apart from the amply distinct *L. sinaloensis* and *L. oaxacensis*, it is apparent that the remaining plants of this group fall into two ill-defined but generally recognizable assemblages: on the one hand *L. guatemalensis* and *L. darienensis*

(which I am unable to interpret as anything but a depauperate phase of *L. guatemalensis*) and, on the other, *L. megalanthus*, *L. proteranthus* and *L. mexicanus*. The more tangible characters separating the two assemblages appear to be the following:

Flowers 13 (rarely 12)–21 mm long; calyx in anthesis generally 7 mm wide or more, usually sparsely sericeous (except in *L. mexicanus*); rachis of inflorescence glabrate; secondary peduncles usually 2–2.5 mm long . . . *L. megalanthus*, *L. mexicanus*, and *L. proteranthus*.

Flowers 10–13 mm long; calyx in anthesis generally 6 mm wide or less, usually densely sericeous; rachis of inflorescence densely canescent; secondary peduncles usually 0.5–1 mm long . . . *L. guatemalensis* (including *L. darienensis*).

These apparently salient characters are not found to be consistently correlated, however. Thus *Hinton 13745*, has secondary peduncles up to 2.5 mm long, the calyx sparsely pubescent and the rachis glabrate, but the flowers are only 11–12 mm long and the calyx only 4–5 mm wide; *Galeotti 1756* likewise has secondary peduncles 2.5 mm long and calyx often 7 mm wide but copiously sericeous, whereas the rachis is canescent and flowers rarely as long as 13 mm; *Ortega 5111*, with predominently *megalanthus* characteristics, the flowers attaining a length of even 18 mm, has rudimentary secondary peduncles; *Rose et al. 14516* has the sparsely sericeous calyx, glabrate rachis and somewhat larger bracts of *L. megalanthus* but secondary peduncles only 1.25 mm long, calyx 6 mm wide and flowers 11–13 mm long; *Lundell 2740* is *L. guatemalensis* except in wide calyces; *Gentle 2483* is *L. guatemalensis* except in long secondary peduncles, etc.

Transitional forms between typical *L. guatemalensis* (including *L. darienensis*), on the one hand, and *L. megalanthus*, *L. proteranthus* and *L. mexicanus* on the other are sufficiently frequent, in fact, as to vitiate any attempt to maintain the latter three as species. Yet because they are so readily recognizable in their extreme forms (particularly *L. megalanthus* with its strikingly showy flowers almost twice the size of those of *L. guatemalensis*), the following new combinations may prove useful to those who wish nomenclatorial designation for such extremes. The varietal category seems to be appropriate as indicating their geographic segregation: *L. megalanthus* being restricted, so far as known, to a relatively narrow area in western Mexico from Sinaloa south to northwestern Michoacán, *L. mexicanus* to southern Veracruz near the eastern coast of Mexico, and *L. proteranthus* to Panama, whereas typical *L. guatemalensis* is predominently a tree of Guatemala, British Honduras, El Salvador, and Honduras, with outlying posts in Sinaloa, Yucatán, Nicaragua, and Costa Rica.

Lonchocarpus guatemalensis Benth., var. **megalanthus** (Pittier), stat. nov.

L. megalanthus Pittier, Contr. U. S. Nat. Herb. **20**: 70. 1917.

Collections typical of this extreme are: NAYARIT: Tepic, *Palmer 1997* (F; US). JALISCO: San Sebastián, *Mexia 1784* (F; US) and *1870a* (US). MICHOACÁN: Aquila, Dist. of Coalcoman, *Hinton 15818* (US).

A fruiting collection (*Ortega 6353*) from Sinaloa can be only tentatively referred here, since it lacks peduncles and pedicels as well as flowers.

Lonchocarpus guatemalensis Benth., var. **proteranthus** (Pittier), stat. nov.

L. proteranthus Pittier, l.c. 63.

Lonchocarpus guatemalensis Benth., var. **mexicanus** (Pittier), stat. nov.

L. mexicanus Pittier, l.c. 71.

The plants of the whole *guatemalensis*-alliance may be distinguished as follows:

Bractlets broadly orbicular, 2 x 2.5 mm; secondary peduncles (3–5 mm long) terminated by a projection of the axis 1–1.5 mm long . . . *L. sinaloensis*.

Bractlets oblong or ovate, 1 mm or less long and wide; secondary peduncles without a projection or when rarely present this rudimentary (0.5 mm long or less).

Leaflets tomentellous beneath; calyx teeth prominent in anthesis; secondary peduncles slender, 3–6 mm long . . . *L. oaxacensis*.

Leaflets glabrous or early glabrescent; calyx teeth shallow or obsolete in anthesis; secondary peduncles stout, 0.5–2.5 (rarely 3) mm long.

Flowers 10–13 mm long; calyx in anthesis generally 6 mm wide or less, usually densely sericeous; rachis of the inflorescence densely canescent; secondary peduncles usually 0.5–1 mm long . . . *L. guatemalensis* (including *L. darienensis*).

Flowers 13 (rarely 12)–21 mm long; calyx in anthesis generally 7 mm wide or more, usually sparsely sericeous (except in var. *mexicanus*); rachis of inflorescence glabrate; secondary peduncles usually 2–2.5 mm long.

Calyx densely silvery-sericeous, almost black in appearance (actually very dark red); leaflets broadly rounded at base (Veracruz) . . . *L. guatemalensis* var. *mexicanus*.

Calyx sparsely silvery-sericeous; leaflets tapering at base.

Mature pods relatively smooth and coriaceous; calyx dark red (Panama). *L. guatemalensis* var. *proteranthus*.

Mature pods scarious (?); calyx pale reddish brown (Sinaloa to Michoacán). . . . *L. guatemalensis* var. *megalanthus*.

Obituaries

ALBERT FRED WOODS, distinguished agricultural scientist, administrator, and educator, died at Prince Georges General Hospital near Washington, D. C., on April 12, 1948, after an illness of five months. He was born on December 25, 1866, at Belvedere, Ill., and grew up on his father's cattle ranch in Nebraska. He is survived by his wife, Bertha Davis Woods, and by two sons, Mark Winton, of the National Institutes of Health, and Winton de Ruyter, a lawyer of Dayton, Ohio.

His collegiate education was obtained at the University of Nebraska. From this institution he received the degrees B.Sc. in 1890, A.M. in 1892, and D.Agr. in 1913. Further degrees were conferred by St. Johns College, Annapolis, Md. (LL.D., 1923), and the University of Maryland (Sci.D., 1932).

At the beginning of his career Dr. Woods served as assistant botanist at the University of Nebraska (1890–93) under the renowned botanist Prof. Charles E. Bessey. While there he prepared a beautifully illustrated account of the Characeae of Nebraska, which was published as part of a general flora of the State.

During the last two decades of the nineteenth century the science of plant pathology was comparatively new in this country. In the U. S. Department of Agriculture this field of research had its official beginnings in 1886, at which time the Congress included in its appropriation a clause that provided for "investigating the needs of diseases of fruits and fruit trees, grains, and other useful plants due to parasitic fungi. . . ." Early approaches to this subject had hitherto been focused mainly on the fungi concerned. The experience of workers with plant diseases, however, had been gradually forcing them to the conclusion that the problems of pathology and physiology of plants are so intimately related as to make impossible any satisfactory solutions in pathology without entering the field of physiology. Dr. Woods's university training and experience, together with his early farm background, had peculiarly fitted him for this combined type of work. To fill this crucial need in the Federal Department of Agriculture in 1893 he was brought in as assistant chief and first assistant physiologist of its Division of Vegetable Pathological and Physiological Investigations and served in these capacities until 1901.

Prominent among his research publications during this period were those on water as a factor in the growth of plants, principles of pruning and care of wounds, the Bermuda lily disease, the mosaic disease of tobacco, fumigation of greenhouses and cold frames with hydrocyanic-acid gas, the stigmonose of carnations, and inoculation of the soil with nitrogen-fixing bacteria.

With the organization of crop research under the new Bureau of Plant Industry established in 1901, Dr. Woods was appointed pathologist and physiologist and assistant chief. His new duties made it necessary to give more of his time and attention to administrative affairs. Although deeply interested in administration, he preferred research—that was his first love. Illustrative of his inner feelings was the following advice to his son Mark, when a high-school student carrying out experiments in his basement laboratory: "If you have a chance to choose between research and administrative work, choose research." One of Dr. Woods's greatest assets as an administrator was this basic regard for research. He felt that administration should always be an actual part of research, and in all the administrative positions which he held throughout his entire active career this principle remained his guiding star.

Over these years numerous articles from his pen appeared in various journals and as Department publications. These included critical appraisals of the relationships of nutrition to plant health and of plant physiology to horticultural and agricultural development. Even at this early day, Dr. Woods had placed special emphasis on the importance of obtaining disease-resistant

plants by selection or hybridization. He emphasized further that "the more we can learn of the exact nature of the normal and pathological processes taking place in cells and cell complexes the better able we shall be to get control of these changes for the good of man." In 1904, a syllabus for introductory courses in botany for agricultural students was the subject of the report of a committee of the Association of Land-Grant Colleges, of which Dr. Woods was chairman. There were also articles on fertilizers for special crops, the status of the nitrogen problem, and wastes on the farm. These further illustrate in some measure the breadth of his interests.

In 1910, he left the Department service to become dean of Minnesota Agricultural College and director of the Experiment Station. In 1917 he resigned from this position to accept the presidency of Maryland State College of Agriculture. Three years later he became president of the University as a whole and brought this institution to a Class A rating. During this period in Maryland (1917–26) he also served as executive officer of the State Board of Agriculture.

Under appointment as director of scientific work, Dr. Woods returned to the Federal Department of Agriculture in 1926, and served in that capacity until 1934. He was also director of its Graduate School from 1926 to 1941 and later emeritus director and educational adviser to the end of 1946. Under his guidance an able faculty was assembled and sound courses of study and high standards of work were established.

Under presidential appointment, Dr. Woods was a delegate to the International Conference on Agriculture at Rome in 1905; he was also a delegate to the International Botanical Congress at Vienna in the same year. He was general chairman of the Committees on Food Production and Conservation of the Maryland Council of Defense in 1917; president of the First Inter-American Scientific Conference on Agriculture, Forestry, and Animal Husbandry at Washington, D. C., in 1930; and member of the International Committee for Intellectual Cooperation of the League of Nations. For several years he served as vice-president of the Board of Trustees of International Biological Abstracts; in this capacity he was instrumental in arranging for its close cooperation with the Department of Agriculture.

He held memberships in the following scientific organizations, including high offices in many of them: American Association for the Advancement of Science (Fellow), American Phytopathological Society (charter member), American Horticultural Society, American Society of Naturalists, Washington Academy of Sciences, Botanical Society of Washington (charter member), Society of Morphology and Physiology, American Academy of Political and Social Sciences, National Research Council, and Association of Land-Grant Colleges and Universities. He also belonged to the Alpha Tau Omega, Alpha Zeta, Gamma Sigma Delta, and Sigma Xi fraternities, to the Cosmos and University Clubs of Washington, and to the Farmers' National Congress (life member).

Dr. Woods's most outstanding contributions to science concerned the virus mosaic disease of tobacco and the oxidizing enzymes in both plant and animal cells. He was among the first to give scientific proof of the infectious nature of tobacco mosaic and the first to call attention to the fact that viruses are associated with specific enzymic disturbances. For many years he had longed to follow up his early work in the light of the newer knowledge and techniques. It was therefore a source of keen gratification—after his retirement from the University of Maryland and the classified service of the Federal Department of Agriculture—that he was able again to work on some of these basic problems. In these later studies of the effects of viruses and mutant mitochondria on certain oxidizing enzymes of the cell, Dr. Woods showed that both virus infection and mitochondrial mutation are able to induce far-reaching changes in enzymic action. The main difference he found to lie in the fact that the viruses are infectious, whereas the mitochondrially induced changes are not. His studies in this field have had a stimulating influence on certain fundamental investigations of the viruses and of the mechanisms by which they act in both the plant and animal organisms, as well as of the mechanisms involved in the development of cancer.

Dr. Woods was a kindly man—always thoughtful of the welfare of others, a point on which the writer, a Vermont graduate who entered the Federal Department of Agriculture in 1908, has been able to testify over the years. He was always cooperative—both as a person and as an administrator. He was among the first to lay

especial stress on the importance of cooperation among individual scientists and between the Department and the State experiment stations. He was friendly and unassuming, and an inspiration to all who came in contact with him. At the time of his death a man well known in educational circles commented thus upon him: "He was the most honest man I have ever met. Much of the good that I may have accomplished in my life I owe largely to him." In his religious outlook Dr. Woods was a liberal; he had a strong Christian faith and tried to put it into practice in his own life and relationships, but he was always extremely tolerant of the attitudes of others. He had that gift of rare personality which enabled him to stand out among his fellows as scientist, as administrator, as educator, and above all as a man.

FREDERICK V. RAND.

PHILIP SIDNEY SMITH was born in Medford, Mass., on July 28, 1877, and died at St. Albans, Vt., on May 10, 1949. He is survived by his wife, the former Lenore Willis Kinney; a son, Sidney Butler Smith, director of libraries of the University of Ver.nont at Burlington; two daughters, Katherine Smith, of St. Albans, and Constance Smith Thurrell, of Denver, Colo.; and three grandchildren, Margaret Katherine Thurrell, Robert Freeman Thurrell, and Peter Westgate Thurrell. Dr. Smith's death was unexpected. He left his home in Washington on April 28 to attend a meeting of the directors of the Arctic Institute of North America in Montreal and went from there to the home of his daughter in St. Albans, Vt. He was stricken suddenly with pneumonia and died the following week. He was buried at Wolfeboro, N. H., near which place his family has had its summer home for many years.

Dr. Smith was of old New England stock. He was the only son of Sidney L. Smith and Kate Butler Smith, from whom he inherited a keen mind and strong body. His early education was at the Boston public schools and Boston Latin School and at Riverview Military Academy of Poughkeepsie, N. Y. He entered Harvard College in 1895 and graduated with the B. A. degree in 1899. After graduation he remained at Harvard as assistant and instructor of geology and physiography and carried on postgraduate work in these subjects, receiving the M. A. degree in 1900 and his Ph. D. in 1904. He was married to Lenore Willis Kinney, of Roxbury, Mass. in 1900.

Dr. Smith's early ambition was to enter the Navy, which is readily understood as his father was a retired naval officer. However, an undergraduate course in geology under Professor Shaler opened to his mind a new, previously unknown subject and from that time on the study of earth forms and processes became his absorbing interest. Geologic field work in Michigan and South Dakota impressed on him the need for wider experience than his teaching afforded, and in 1906 he left Harvard to join the Alaskan Division of the United States Geological Survey. Several years of Alaskan exploration followed, but his unusual administrative ability was so evident that in 1915 he was appointed Administrative geologist and later acting director of the Survey.

After the death of Col. Alfred H. Brooks, chief Alaskan geologist, Dr. Smith was appointed as his successor and continued as chief geologist of the Alaskan Branch from 1925 until he himself retired from public service in 1946. Although this period of more than 20 years was occupied in large part with administrative duties that interfered with extended field trips, it included two remarkable exploratory expeditions that were undertaken by him for the United States Navy as part of the study of petroleum reserves on the Arctic slope of Alaska, one in 1924, the other in 1926; a journey to the East India Islands as official delegate to the Pan-Pacific Scientific Congress, Java, 1929; an assignment of eight months as supervising engineer for the Federal Emergency Administration of Public Works in Alaska in 1933–34; and a journey to Russia as chairman of the United States delegation to the Seventeenth International Geologic Congress, U.S.S.R in 1937.

Dr. Smith is the author of many bulletins, professional papers, and other publications, dealing with Alaskan geology, mineral resources, and related subjects. His compilation and analysis of the geologic information collected by himself and other Alaskan geologists, published in 1939 under the title *Areal geology of Alaska*, is evidence of his own wide grasp of the subject and is the authoritative statement of the progress of Federal geologic surveys in Alaska up to the time of its publication. He spared himself no pains in his endeavor to express his own ideas with clearness and a precise use of words, of which his mind

had a great store. He was a most thorough and helpful critic of work submitted to him by others.

Dr. Smith's various interests in earth studies is shown by his membership in national or local geologic, geographic, and other scientific or engineering societies. He was either fellow or member of the following organizations: Geological Society of America, American Association for the Advancement of Science, Association of American Geographers, Society of Economic Geologists, Society of American Military Engineers, American Geographical Society, National Geographic Society, Washington Academy of Sciences, Geological Society of Washington, American Institute of Mining and Metallurgical Engineers, American Polar Society, American Geophysical Union, Society of Professional Geographers, Science Committee, National Council of American-Soviet Friendship, Inc., and Arctic Institute of North America. In addition to membership in scientific and technical societies, Dr. Smith was a member of the Loyal Legion, Delta Upsilon Fraternity, Cosmos and Harvard Clubs of Washington, Travellers Club of Harvard, and Explorers Club of New York.

After his retirement in 1946, Dr. Smith devoted himself to writing, but gave much of his time and thought to the work of the Arctic Institute of North America, of which he was a charter associate and a member of the Board of Governors. His own experience in geologic exploration north of the Arctic Circle stimulated his interest in all problems relating to arctic conditions and thus opened an inviting field of investigation for his inquiring mind.

All who knew Dr. Smith will remember him for his hearty laugh and his unaffected friendly greeting, his keenness of mind, and his apt reply. Those who knew him best will remember him further for his unselfish generosity, his inquisitiveness that was never satisfied, and his love of books. He was a thorough believer in the idea of competition whether in work or in play, yet had more satisfaction in the feeling of having played his hand to the full than in winning the game. He had positive ideas and was firm in supporting them. Vigorous, forceful, humorous, with his analytical mind ever on the alert, impatient of anything less than perfection either in himself, or in others, he was an inspiring and stimulating companion and an invaluable friend.

FRED H. MOFFIT.

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